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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 47, No. 10

OCTOBER, 1919

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological table dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books, and (*c*) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, winds, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library, U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

SOME WEATHER BUREAU PUBLICATIONS.

Serial numbers of Weather Bureau publications	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
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National Weather and Crop Bulletin, with charts, weekly	25 c. a year.
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Climatological Data, monthly for 42 separate sections, each section 5 c. a copy	50 c. a year.
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As the surplus of MONTHLY WEATHER REVIEW, February, April, and July, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

CORRIGENDA.

REVIEW, August, 1919:
Page 578, column 2, name of the 5th author "Miles, Enos A." *should read* "Mills, Enos A."
REVIEW, September, 1919:
Page 624, 2d column, 16th line from bottom, "figures 1–4" *should read* "figures 3–6."
Page 630. The legend under "Fig. 16" belongs to "Fig. 17." The legend under "Fig. 17" belongs to "Fig. 16."
Page 653, 1st column, 21st line from top, "0.61° C. in January and 0.45° C. in July" *should read* "0.45° C. in January and 0.61° C. in July."

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

VOL. 47, No. 10.
W. B. No. 696.

OCTOBER, 1919.

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THE EVOLUTION OF THE SNOW CRYSTAL.[1]

JOHN C. SHEDD, Professor of Physics, Occidental College.

The snow crystal, solidifying as it does from the vapor of the atmosphere, is formed under circumstances exceptionally favorable to freedom of movement of the molecules. The passage of the material of which the crystal is made direct from the vaporous to the solid state, without passing through the liquid stage, is a circumstance not generally met with. These facts, no doubt, account for the great variety of crystal form observed, a variety not approached by any other mineral. It is, however, not so clear as to what determines the formation of one or other of the various types.

Of the observers, both in Europe and America, who have devoted their attention to the study of snow crystals Mr. W. A. Bentley, of Jericho, Vt., has undoubtedly gathered the most extensive and valuable body of data in existence. During the past 37 years he has each winter secured microphotographs of snow forms, until his collection now comprises over 3,000 negatives. In the U. S. MONTHLY WEATHER REVIEW for 1902 he gives an interesting summary of his work up to that date, together with reproductions of 255 microphotographs.

In 1899, while at the University of Wisconsin, I had the opportunity of seeing a large number of lantern slides made by Mr. Bentley. In 1900, on removal to Colorado College, I secured a set of some of these slides and from that time have endeavored to study the general problem. After several seasons of more or less systematic observation, however, without the aid of photography, of snow forms as found on the eastern slope of the Rocky Mountain range at the elevation of 6,000 feet, together with a study of Mr. Bentley's paper, I began to reach some interesting conclusions. These were published in April, 1905 and June, 1906.[2] in the "Colorado College Studies."

An important part of Mr. Bentley's work is contained in the tables he gives showing the distribution of the various types of crystals with respect to (1) storm section, (2) temperature, and (3) cloud source. This is summarized in the following tables taken from my former paper.

The crystals in the tables are divided by Bentley into seven classes as follows: (1) Columnar, (2) solid tabular, (3) stellar-nucleus (having solid centers), (4) fern-stellar, (5) doublets, (6) needle-shaped, and (7) granular.

TABLE 1.—*Distribution of snow crystals of various types for 131 general Vermont storms, years 1897 to 1902.*

Storm section.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
N.	22	19	25	17	3	6	8
NE.	14	19	24	10	14	5	14
E.	22	11	15	26	4	11	11
SE.	25	25	25	25	0	0	0
S.	0	5	10	40	5	10	26
SW.	13	16	19	23	8	3	18
W.	9	21	25	22	5	5	13
NW.	5	20	23	22	7	22	20
Central.	12	12	18	19	13	8	17
Undetermined.	8	16	26	20	0	2	26
Distribution for 14 local storms, 1901-2.	7	0	13	27	0	0	53
Grand total for all cases.	11	16	21	23	4	5	20

[1] Presented before the Pacific Section, A. A. A. S., Pasadena, Calif., June 19, 1919.
[2] See also Rev. Nephol. Bruxelles, 1907, pp. 145-150.

TABLE 2.—*Distribution of crystals with respect to temperature.*

Storm section.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Medium cold storms +15° F. to +5° F.	23	20	17	14	5	3	20
Very cold storms +5° F. to −10° F.	10	22	26	23	5	4	11

Prof. G. Hellmann in an interesting little book entitled "Schneekrystallen," printed in Berlin in 1893, cites figures for the three types (2), (3), and (4). Taking these types by themselves the following table results:

TABLE 3.

Temperature.	(2)	(3)	(4)		Observer.
	Pct.	Pct.	Pct.	Pct.	
21.2° F. to 18.5° F.	26	22	52	31	Hellmann (Berlin).
15.8° F. to 9.5° F.	57	19	24	21	Hellmann (Berlin).
15° F. to 5° F.	40	34	28	39	Bentley (Vermont).
+5° F. to −10° F.	30	37	33	47	Bentley (Vermont).

TABLE 4.—*Distribution of crystals with respect to cloud sources during 67 storms, winter of 1901–2 (Bentley).*

Character of clouds.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Cumulo-nimbus.	2	0	15	35	0	7	41
Stratus and nimbus.	20	13	20	27	13	6	0
Cirro-stratus and nimbus.	6	16	20	20	4	6	28
Stratus.	16	33	33	0	0	0	16
Cirrus.	0	0	0	0	0	0	0
Cirro-stratus.	32	23	23	18	0	5	0
Cirrus and cumulus.	11	11	22	22	11	0	22

In considering the foregoing tables the following remarks by Mr. Bentley should be carefully noted: "It will be noted that the cirrus and cirro-cumulus clouds have deposited no snow crystals. These clouds, when occurring alone, very rarely, if ever, deposit crystals of sufficient size to fall to the earth. * * * When nimbus or stratus clouds are present the existence of cloud strata lying above the lower clouds can not be certainly determined, but have been inferred from general considerations. In general, the snow forms are most frequent when two or more cloud strata exist. * * *"

For a more complete discussion of these tables both Mr. Bentley's and my articles should be consulted. The conclusions which I reached from their study are as follows:

(1) The open-structure type of crystal (frequently called the "Fern-stellar" type) is on the whole of the most frequent occurrence. Bentley himself remarks: "The preponderance of the branching open-structure crystals and granular forms will be noted, and it may be added that such types actually form a larger percentage of the total mass of crystals than is indicated by the figures.

(2) They are numerous in the case of local storms; in general storms they seem to be most numerous in the southern segment.

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(3) They are more frequent at low temperature than at high temperature (Bentley). The reverse is true (Hellmann). The contradiction here found may be ascribed to the small number of cases examined by the respective observers.

As the number of observations increased, I should expect Prof. Hellmann's conclusion to be verified rather than Mr. Bentley's. To this, however, there would be notable exceptions [see (8) below] for the question of surface temperature is far from conclusive. Other factors would need to be considered, such as the humidity, both absolute and relative—the presence or absence of more than one cloud stratum; atmospheric turbulence and wind velocity, conditioning the length of time the crystal is kept aloft.

(4) They are abundant in the case of low-lying clouds.

(5) Crystals having solid centers are most frequent in the case of high-lying clouds. At low temperatures these classes gain at the expense of the granular type.

(6) The granular type occurs frequently when the the temperature is high and in local storms; it is not frequent at low temperatures.

(7) The doublets and needle-shaped crystals are infrequent at best and occur about equally at all temperatures; double-cloud strata seem to be favorable to their formation.

(8) In the case of light snow, falling sometimes from an apparently clear atmosphere, careful observations in Colorado convinced me that the crystals from low altitudes, below 3,000 feet, are always of the open-structure type while those from high altitudes are preponderantly of the closed-structure type. My paper of June, 1906, is taken up with a discussion of this point.

(9) In regard to some of the rarer forms, doublets and needle-shaped forms, when they occur they come in large numbers as if the conditions which produced them precluded the formation of the more common tabular type.

With the preceding studies as a basis it seems possible to formulate the following general hypothesis in regard to the formation and transformation of tabular snow crystals:

First.—All snow crystals of the tabular type have their origin in the open-structure crystal. (See figs. 1 to 12.)

Second.—The solid hexagon is the final form to which all tabular crystals tend. (Figs. 29 to 34; 136 to 145; 170 to 172.)

Third.—There is a transformation from the primitive to the final forms, this process being subject to many varying conditions which leave their impress upon the crystal.

Fourth.—There are two general transition processes; first a process of accretion in which new material is added to the crystal; second a process of transformation in which the losses and gains result in a change in arrangement of material, a reduction in size and generally in mass also.

The process of accretion is to be regarded as a rapid one taking place whenever the crystal is in an atmosphere tending toward supersaturation. Under these conditions the growth is of the "fern-leaf" type and is readily recognized. (Figs. 12, 48, 152.) The rapidity of growth is shown in the lack of symmetry.

On the other hand, the transformation process takes place in an undersaturated region and consists not only of losses due to gradual evaporation from the outlying parts of the crystal but also to gains due to still more gradual condensation about the center of the crystal. The slowness of the process is shown in the filling in of the open spaces, in the completion of the hexagonal figure of the crystal and still more in the wonderful symmetry manifested in every detail of the pattern developed. Time is the essential element in this process.

Upon this hypothesis it is now possible to arrange a classification of crystals which shall show, at least approximately, where the crystal belongs, what its history has been and something as to its age. It seeks to place the crystal in accordance with the successive stages of development through which it has passed. The classification is as follows:

Class I. First-growth Crystals.
- I_a. Axes of crystallization alone prominent. Fig. 1 illustrates this crystal.
- I_b. Axes with rapid growth additions. Fig. 8 is a good sample, while fig. 12 seems to show the limit of this stage.
- I_c. First growth crystal modified by evaporation and condensation. This type is frequently met with. Fig. 15 is a good sample.
- I_d. Final completed crystal of first growth. Fig. 29 is a fine example.

Class II. Second-growth Crystals.
- II_a. Secondary axes prominent outside of the *first-growth* center; fig. 38 will illustrate.
- II_b, II_c, II_d, have the same significance as under the First-growth Crystals. Numerous cases will be found in the photographs which follow.

Class III. Third-growth Crystals.
- III_a, $_b$, $_c$, $_d$ have the same significance as above.

Class IV. Fourth-growth Crystals.
- This is the highest stage of growth that I have observed. I do not find any examples in the data herewith presented.

Class V. Special or unusual forms. Here we frequently find that the pathological rather than the normal cases prove the most informing and furnish the most suggestive data.

The above classification has been made to apply primarily to the tabular form of crystal. The columnar and other forms present equally interesting problems, which at present seem to be somewhat more difficult of solution. The groups of crystals 196, 197, 198, some 15 in number, illustrate this class.

The observations of the past 19 years have tended to increase my confidence in the conclusions set forth above. Removal to southern California has put a stop to direct observation, but I have found abundant material for study in photographs furnished me by Mr. Bentley.

The present paper, in so far as it presents new material, is a study of the complete crop of photographs secured by Mr. Bentley during the winter of 1916–17. This selection was made partly because of the enthusiasm with which he spoke of the variety and beauty of that season's crystals. His enthusiasm was entirely justified.

The number of tabular crystals is 211. There are also some 15 of the columnra and doublet types. Some of the "special" crystals have proved especially interesting.

There are several features among the present collection of photographs which call for more than a passing word.

First, it is well worth while to pause for a moment and consider the line patterns of many of the crystals They constitute one of the, as yet, unsolved problems connected with snow-crystals. It is the opinion of students of the subject that these lines are air tubes. G. Hellmann of Berlin discusses them as follows:

> The most remarkable feature of the structure of the primary and secondary rays lies in the capillary cavities which they contain. * * * Attention was called to them as early as 1681 by Rossetti and by Wilcke at a later time. * * * It was in the laminar snow crystal that I observed them for the first time, for they are usually larger there and thus more easily seen * * * the inner distance between the capillary tubes is ordinarily from 0.02 to 0.05 mm. and the largest diameters of the tubes themselves are of about this order of magnitude. * * *

Second: Several of the individual crystals reward careful study. These fall into the following groups;

(1) Nos. 188, 189, 190.

(2) Nos. 76, 199, 200.

(3) Nos. 184, 185.

Taking these in order; (1) It is evident that these three crystals were broken and afterwards repaired themselves to the extent shown. In all three cases it must have been necessary for the impaired crystal to pass into a region of high humidity, to build up secondary axes and then for the growth on these axes to consolidate. In each of these cases it would appear that the secondary axes formed only on the impaired portion of the crystal. In crystal 189 and 190 we further note that on the repaired portion of the crystal the pattern of the older portion is reproduced.

From the above we are led to conclude:

I. That the force of crystallization, assisted it may be by attendant circumstances of temperature—humidity and electrical state—is much stronger as one approaches the center of the crystal.

II. The restoration of the pattern, as well as the material of the lost part of the crystal, would indicate that the law of symmetry means more than has heretofore been assigned to it. The infinite variety in designs found may be due in their inception to fortuitous circumstances, but the pattern once started is fixed to a degree hitherto unthought of.

(2) Crystals 76, 199 and 200 should be studied together. In 76 and 199 the channels between the sextants are open and extend almost to the center of the crystal. In No. 200 these channels, originally open, are now completely closed. Moreover, the outline of the "filling," showing all the irregularities originally present, seems to show a rapid process of filling in, as if the inhibition had been suddenly lifted and the process of filling rapidly carried out. In my first paper (May, 1905) I made a suggestion in regard to crystals of the form of 199 substantially as follows:

It is permissible to suppose that the particles thrown off by evaporation may carry with them an electric charge, leaving the surface from which they come charged in an opposite sense. Now since the evaporation would be more active at the tips of the crystal than in the angles, the former region would have a stronger charge than the latter. In this way a difference of potential would be established between tip and angle and the charged vapor particles would have a tendency to follow this potential gradient. In other words there would be a net loss of material to the crystal but there would be a transfer from the tips into the angles of the crystal thus tending to build up the solid form of crystal. Next let us suppose (e. g.) that the tips of the crystal are positively charged and the angles negatively charged. Also that the vapor particles in the general region are negatively charged.

The result now would be that since the walls of the angles are negatively charged and the free vapor particles negatively charged, the free particles attaching themselves to the crystal would be less and less deposited on the walls of the angles, thus leaving the channels open and building up the outer portions of the crystal. This effect would only be operative at temperatures low enough to render the crystal a comparative nonconductor, otherwise the charges would be dissipated by conduction.

Finally, if a crystal of this type were to next pass into a stratum which is at a higher temperature, or where the vapor particles are positively charged or neutral; the result of the first would be to dissipate the screening charge by conduction, thus permitting the deposit of vapor particles upon the screened portion, while the second would invite such deposit. In either case, the channel would be rapidly filled up as shown in fig. 200.

(3) Considering next Nos. 184, 185 at first these seem most unusual and strange. Further consideration, however, shows them to be but extreme cases of 199. Two quite different explanations seem possible, (a). Thus, glancing at Nos. 6, 7, 36, 40, 41, 47, 82, 148 and 152 we see that rudimentary growths have started at the middle of the sides of the crystals. Nos. 6 and 7 are first-growth crystals, 40 to 82 second-growth crystals and 148, 152 third-growth crystals. Such growths are of rare occurrence, being found on but 5 per cent of the present data.

If crystals of this sort were now placed under the conditions which produced Nos. 76 and 199 the result would be to produce Nos. 184, 185. These crystals are then to be classed under I_c, II_c or III_c. The fact that they are rarely found would be due to the double fact that the rudimentary start required is rare and the further condition producing 199 is rare.

(b) The second explanation is based upon a recent letter of Mr. Bentley in which he makes the following significant remark in regard to figure 185:

> I have several such. Crystals of this (seeming) shape are quite common in some snowfalls, possibly 1 per cent being of this shape for a brief time. But so far as I am able to learn, the 12-pointed ones really consist of one crystal *superimposed* upon another, and never growing outward on the *same plane*. It would seem as if there must be a short bar or connection at the center, for the rays of the one usually project at an intermediate direction *between* the rays of the other. Yet they are easily detached one from the other. Crystal 185 was so detached after photographing it.

This would connect many, if not all, crystals of the form 184–185 with the doublet crystals shown in No. 196. It would also make each member of such a doublet of the form of 199. The interesting feature is the fact that the axes, or rays, of the two members lie at a 30° angle with each other instead of being parallel as in 196. Remembering that the connecting bar between the two members is exceedingly short, and remembering that the rays of the crystals are electrically charged, it would seem possible to invoke the same electrical action already suggested as responsible for type 199, here also, thereby forcing the axes to place themselves at a maximum distance from each other, as shown in 184 and 185.

As no attempt is made in the present paper to discuss the doublet further comment is reserved for a future time.

Tabular summary of all crystals.

First growth.			Second growth.			Third growth.			Totals.		
Class.	I.	P. ct.	Class.	II.	P. ct.	Class.	III.	P. ct.	Class.	Cases.	P. ct.
	Cases.			*Cases.*			*Cases.*				
I_a	3	=1.4	II_a	7	3.3	III_a	7	3.3	a	17	= 8.0
I_b	10	4.7	II_b	15	7.0	III_b	2	1.0	b	27	=12.6
I_c	22	10.3	II_c	85	39.7	III_c	18	8.4	c	125	=58.4
I_d	12	5.7	II_d	15	7.0	III_d	3	1.4	d	30	=14.0
Total.	47	22.0	Total.	122	57.0	Total.	30	14.0	Total.	199	93.0
									Special	15	7.0

The foregoing analysis of a considerable body of snow-crystal data has been given as an attempt to find, if possible, an adequate method of classification which shall lead eventually to a solution of some of the many interesting and at present apparently insoluble problems connected with this most fascinating subject.

My thanks are due to Mr. Bentley, from whom I secured the photographs, and to Dr. Ford A. Carpenter, meteorologist in charge of the Los Angeles Weather Bureau, and to my student, Harold P. Hamilton, who helped me in looking up references.

CLASS I. First-Growth Crystals.

I_a Figs. 1, 2, 3; strictly speaking No. 1 alone belongs to this subclass, Nos. 2 and 3 having evidently received additional growth which has consolidated. Number of cases 3; =1.4 per cent of total.

I_b Figs. 4 to 12 inclusive (also fig. 186). Number of cases 10; =4.7 per cent. There may be doubt whether No. 4 ought not to be placed under I_c. The effect of such errors will be lessened as the number of crystals classified is increased.

I_c Figs. 13 to 28, inclusive; also Nos. 187, 188, 191, 192, 199, 200. Number of cases, 22; =10.4 per cent. The crystals from No. 19 on might easily be placed in class I_d but it is better to include under I_d only those crystals which have absolutely reached the finished stage, as shown by the *completed* hexagon. It is interesting to note that the notch in the middle of each side seems to be the last part to fill in.

I_d Figs. 29 to 34 inclusive; also Nos. 173, 174, 176, 178, 181, 182. Number of cases, 12; =5.7 per cent. There may be some doubt as to whether Nos. 33 and 34 do not belong under Class II_d. At all events they afford beautiful examples of Nature's masterpieces in symmetry and design.

Total number of cases in Class I, 47; =22.2 per cent.

CLASS II. Second-Growth Crystals.

II_a Figs. 35 to 41 inclusive. Number of cases, 7; =3.3 per cent. All of these samples are excellent. On some the secondary growth has started, as in Nos. 35, 36, 40 and 41. The primacy of the axis is evident. The existence of rudimentary axes at the center of the sides in the case of Nos. 36, 40 and 41 should be noted. Further comment on this will be made later.

II_b Figs. 42 to 56 inclusive. These are excellent samples and show clearly the initial stage of the process of consolidation of the secondary growth.
Number of cases, 15; =7.1 per cent. It is a little puzzling to determine whether a crystal belongs under II_b or II_c. It is also difficult to determine the exact progressive order.

II_c Figs. 57 to 135 inclusive: also Nos. 179, 183, 184, 185, 189, 193. This class is by far the best represented of any. I find that Hellmann in his little book shows 56 photographs, of which 18 per cent belong to this class, as against 40 per cent for Bentley. The colder climate of Vermont would lead one to expect this.
No. 82 shows a well developed secondary axis at the middle of each side. It will be noted that the channels in No. 76 have been kept open clear down to the first order crystal.
Nos. 96–106: The process of consolidation is pretty well on towards completion. The symmetry of the interior pattern will be noted as well as the shaping up of the outer edge. In most cases the line of demarcation between the first and second order crystals is well defined.
Nos. 107–118: It is in crystals of this type that the most exquisite examples of snow-crystal handicraft are to be found. It must have been after contemplating such as these that Olaus Magnus of Upsala in 1555 suggested their use as patterns for designs. It seems strange that the idea has not been carried out in embroidery and stained glass effects.
Nos. 119–130: The crystals on the present plate have reached their final stage of growth. It is likely that most of the crystals that reach this degree of perfection do not complete their growth, or perhaps do so after reaching the ground.
Number of cases, 85; =40 per cent.

II_d. Figs. 136 to 145 inclusive; also No. 194. Number of cases, 15; =7.1 per cent.
Total number of cases under Class II, 122; =57.6 per cent.

CLASS III. Third-Growth Crystals.

III_a. Figs. 146 to 150 inclusive, also No. 194. Number of cases, 7; =3.3 per cent. In all of these crystals the third growth axis is rudimentary only. This, however, is accidental rather than general, for we shall see in the succeeding crystals well developed growths.

III_b. Figs. 151, 152. Number of cases, 2; =1 per cent. Of these 152 is the better example, both are meager.

III_c. Figs. 153 to 169, inclusive. All of these show a heavy growth of the third order. No. 155 is a good sample. No. 158 is an especially good sample. No. 162 is another showing the perfection of detail so often shown by these crystals.
Number of cases, 18; =8.5 per cent.

III_d. Figs. 170, 171, 172, 3 cases; =1.4 per cent. Total number of cases under Class III, 30; =14.2 per cent.

All of these crystals are included in the regular classification as follows:
No. 173, I_d; 174, I_d; 175, II_d; 176, I_d; 177, II_d; 178, I_d; 179, II_c; 180, II_d; 181, I_d; 182, I_d; 183, II_c.
They are grouped together because of some special feature of shape or pattern. Nos. 174, 176 are strangely like triangles though they still follow the hexagonal law of crystallization. It is unusual to find a circle in the line pattern. No. 180 approximates to this. No. 181 has the line pattern broken up into dots, while 182 has a drapery-like pattern which is unusual. No. 178 probably was broken and has been "mended" by the fairy workmen.
All of these crystals are included in the regular classification as follows: No. 184, II_c; 185, II_c; 186, I_b; 187, I_c; 188, I_c; 189, II_c; 190, II_d; 191, I_c; 192, I_c; 193, II_d; 194, III_a; 195, II_a.
Nos. 184, 185 belong in a class by themselves, apparently, but closer study will link them with Nos. 199 and 200 and also with crystals 196. Nos. 186, 187, 188, 189 and 190 have been in the repair shop and have an interesting story to tell.
Nos. 193, 194 and 195 have passed through a fringe of cloud liquid and have caught some of the drops. More of this would give a granulated crystal. No. 195 seems to have been falling without whirling, since one edge has caught all of the drops. This is only occasionally found.
Of these crystals, Nos. 199 and 200 belong in the regular classification; both fall into class I_c. They are however, to be especially studied because of the channels running nearly to the center in each case.
The crystal at the center of the plate is probably a columnar crystal with one end melted down. It may however, be one of the "Flagon" crystals sometimes found. In such case the interior ought to contain a large drop of water. The appearance of the crystal does not seem to indicate this.

CLASS IV. No Fourth-Growth Crystals were found among the present data.

CLASS V. Special or unusual forms.

1. Columnar crystals: groups 197, 198, 11 cases; =5.2 per cent.
2. Doublets: group 196, 3 cases, 1.4 per cent.
3. Pyramidal crystals: group 197, 1 case.

Total of special cases, 15; =7.1 per cent.

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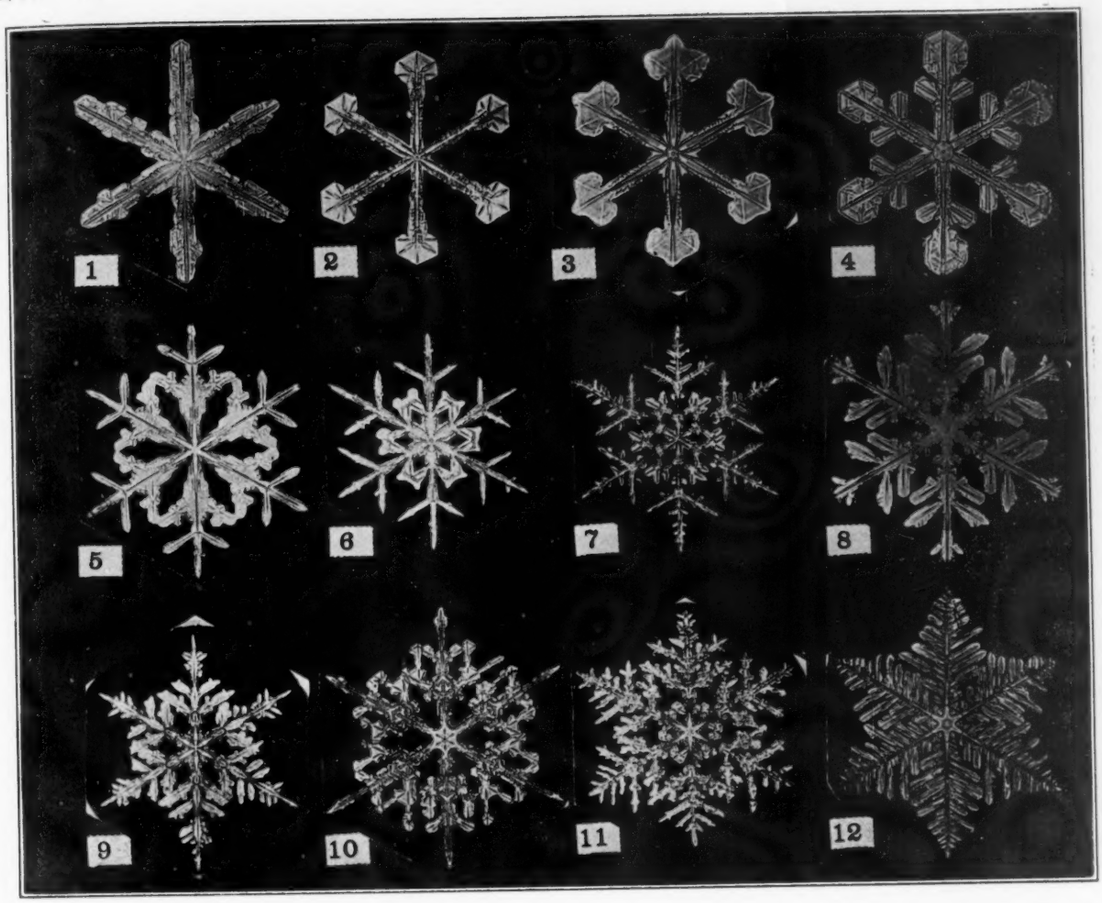

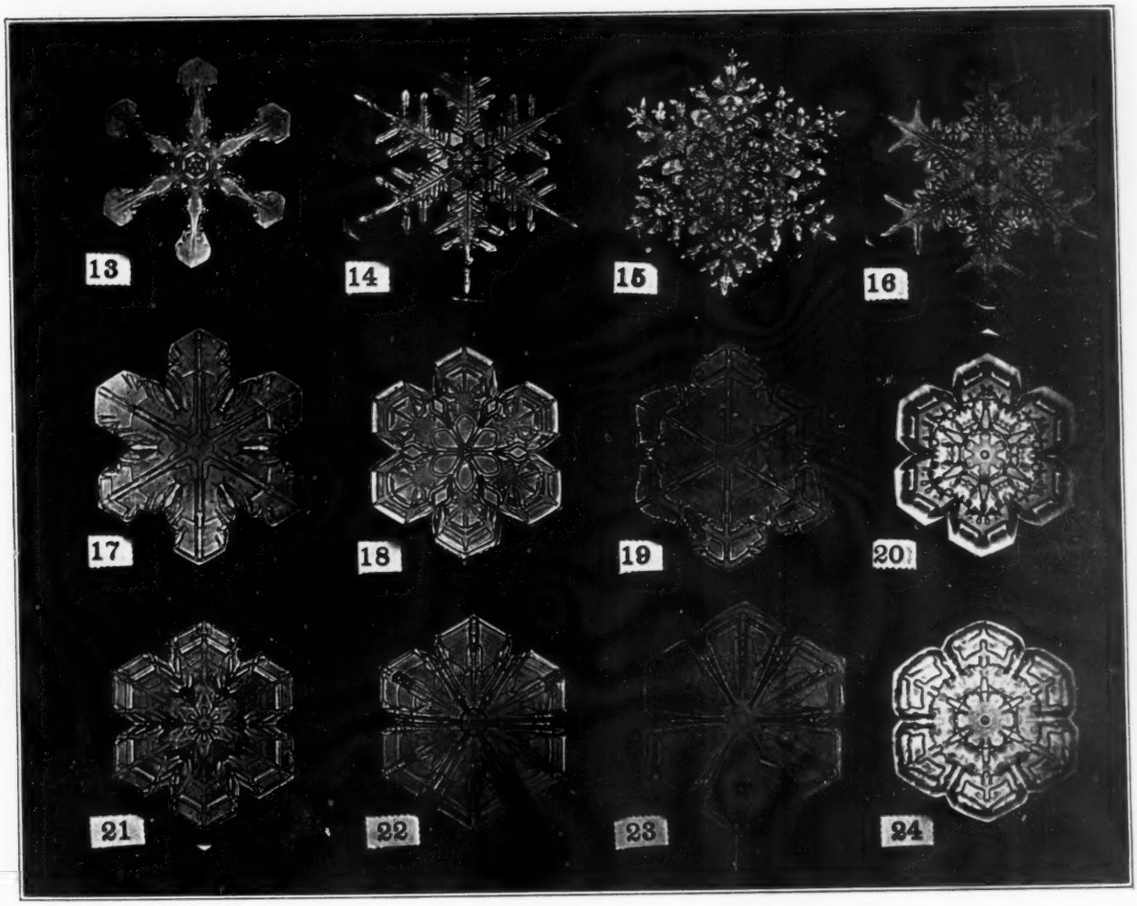

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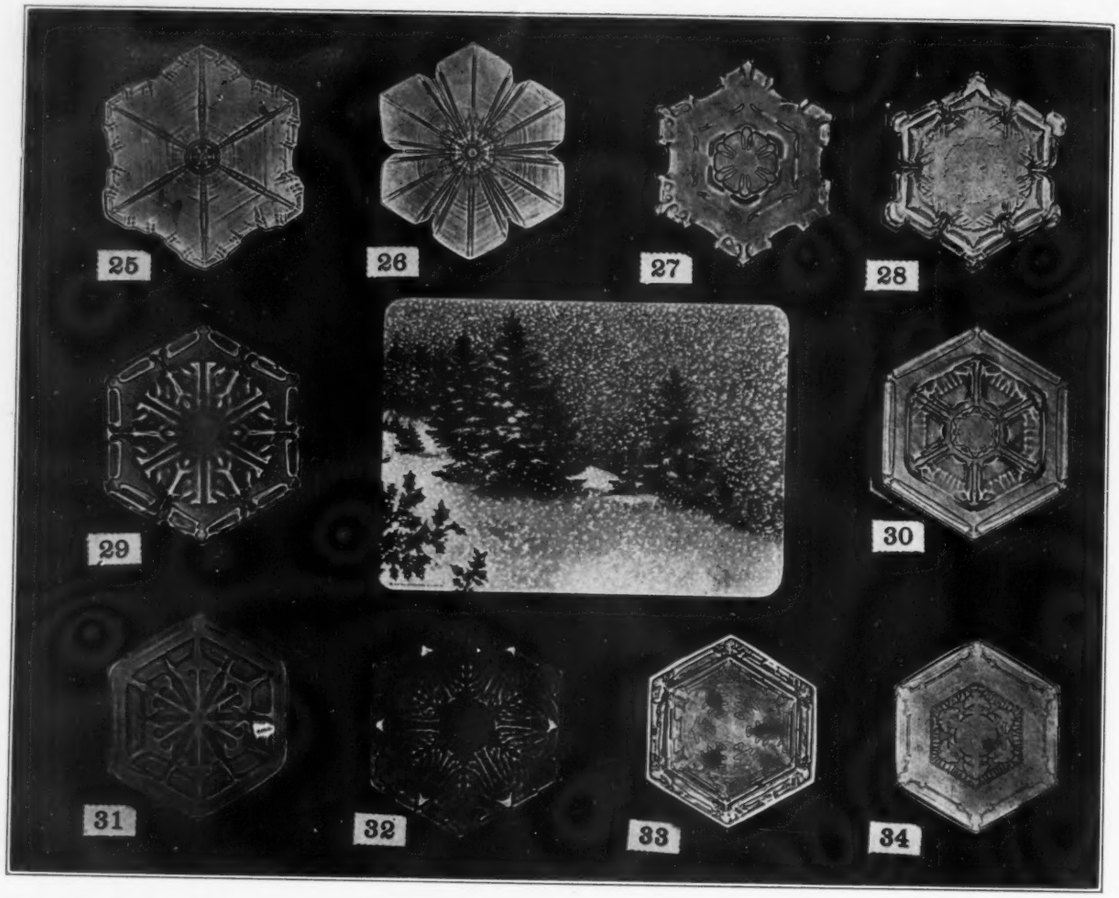

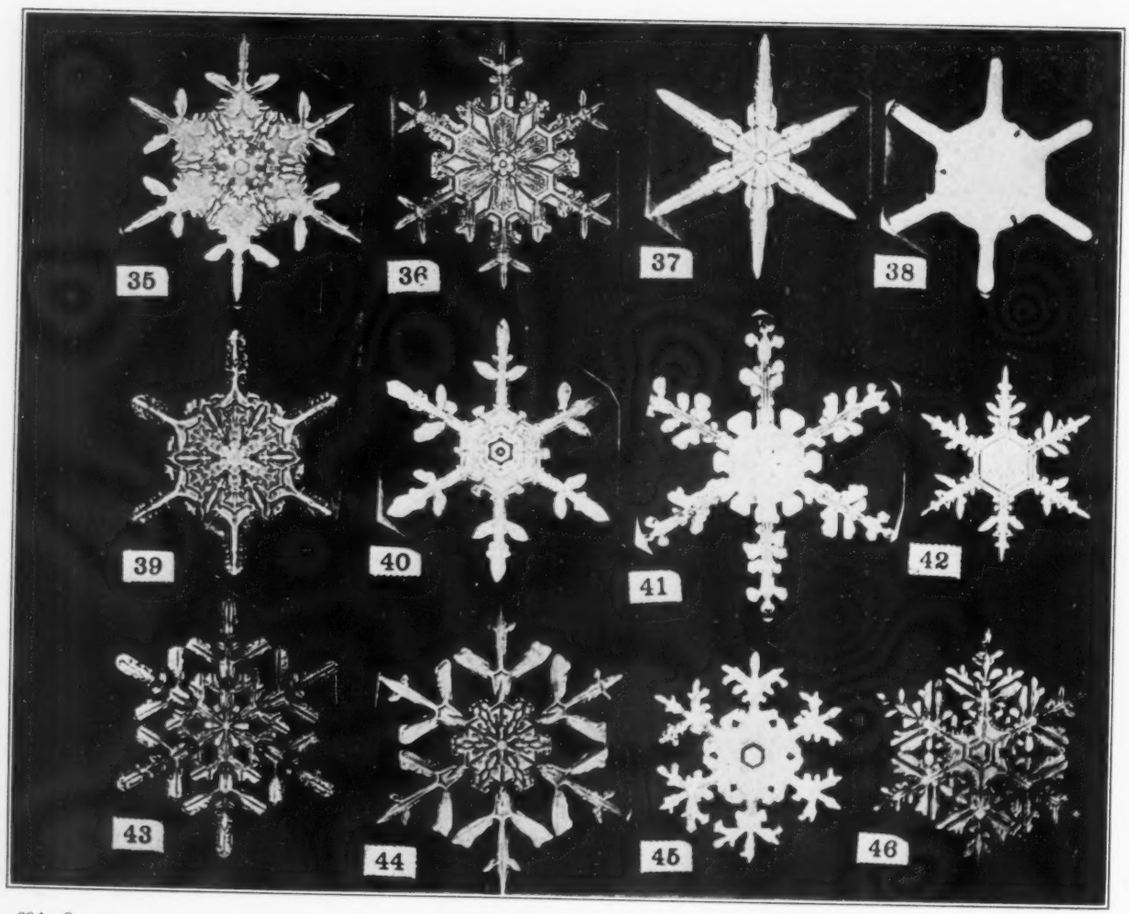

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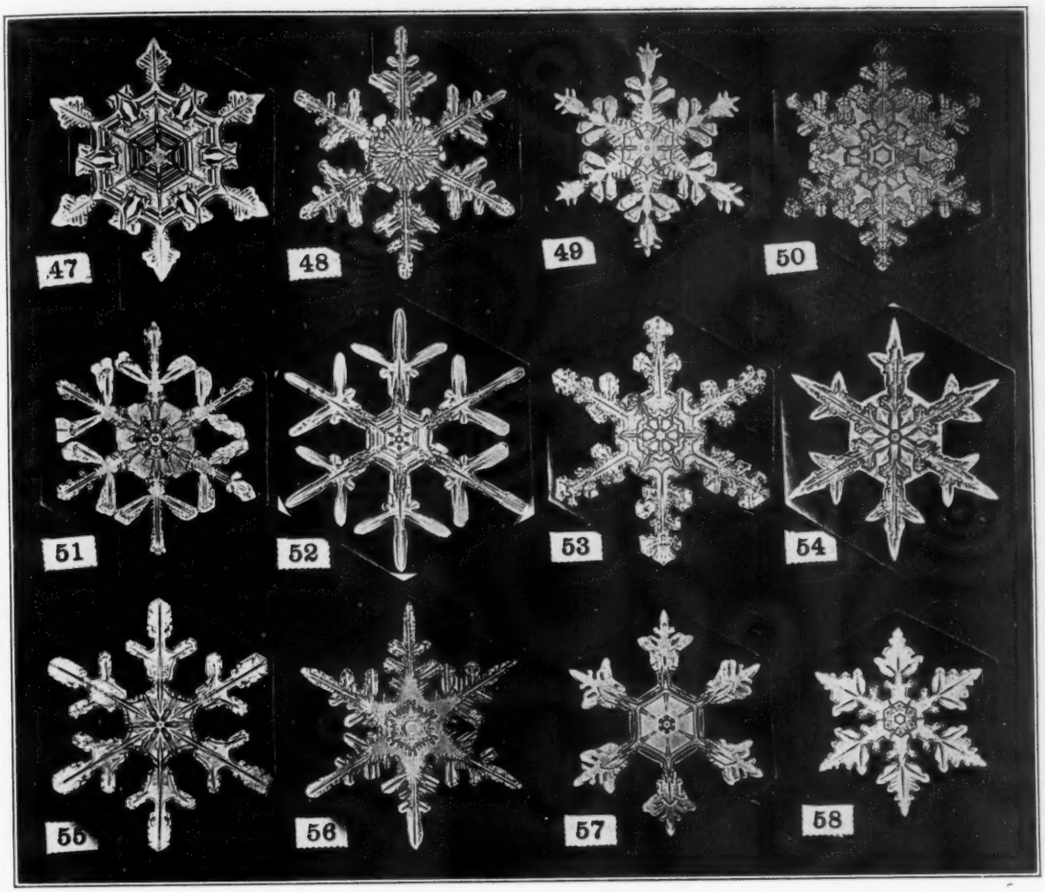

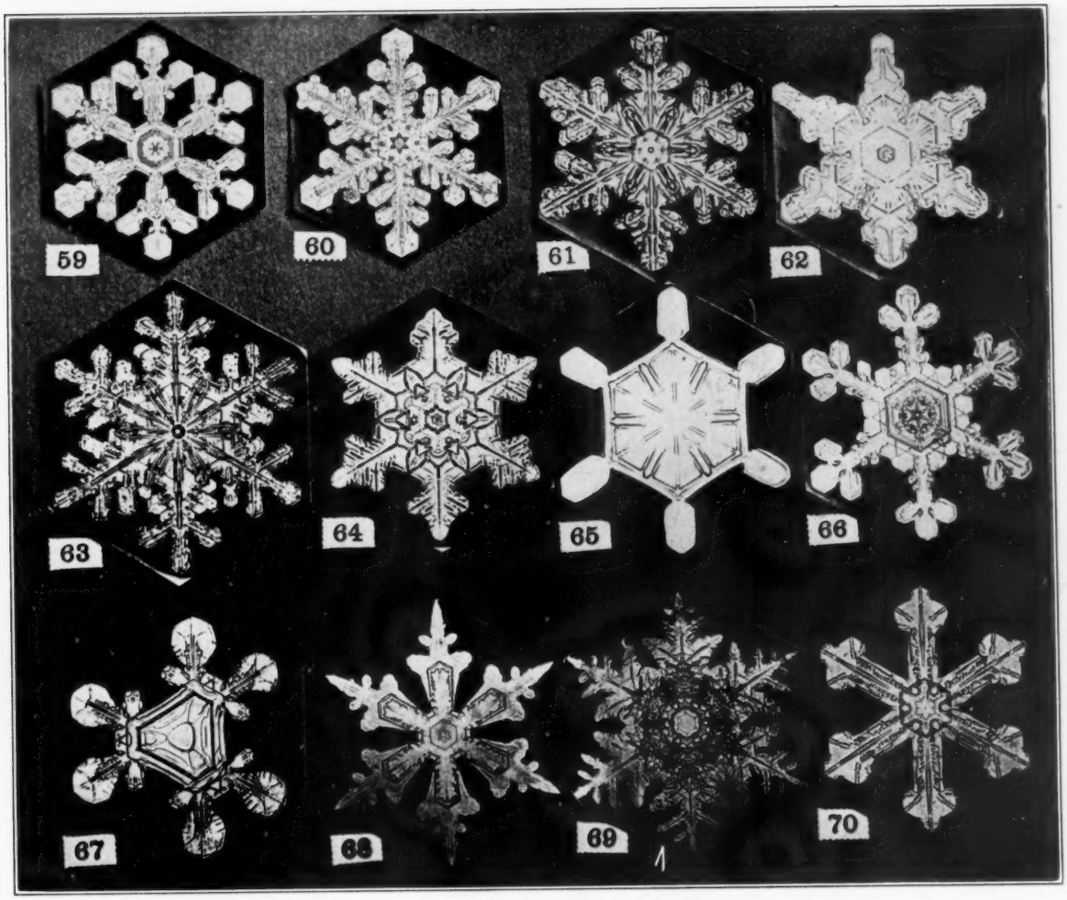

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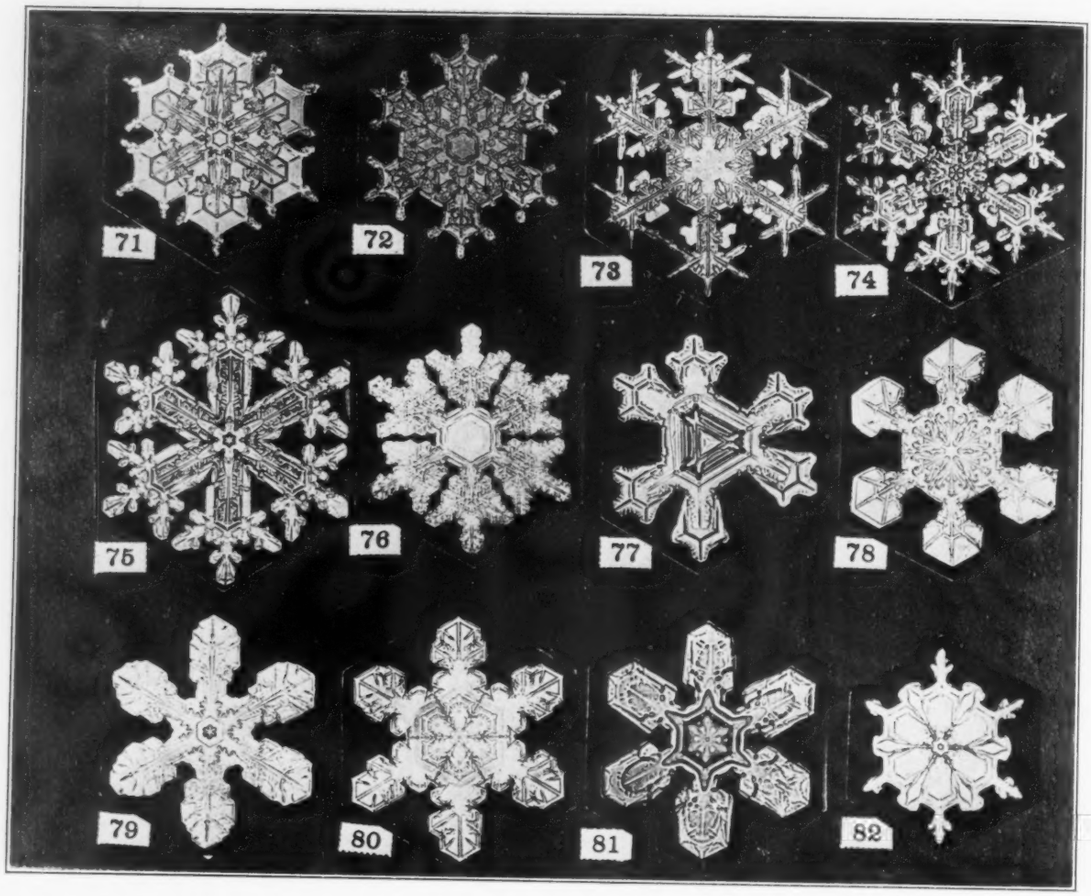

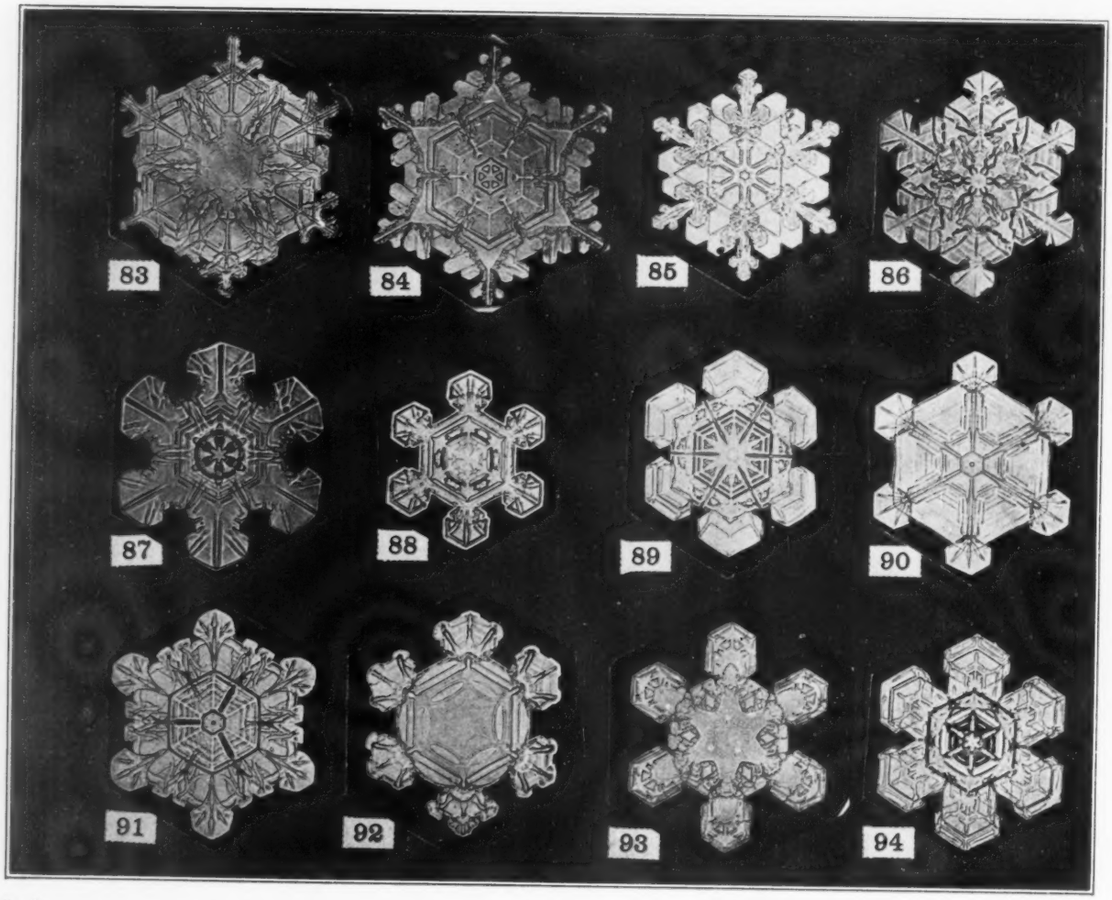

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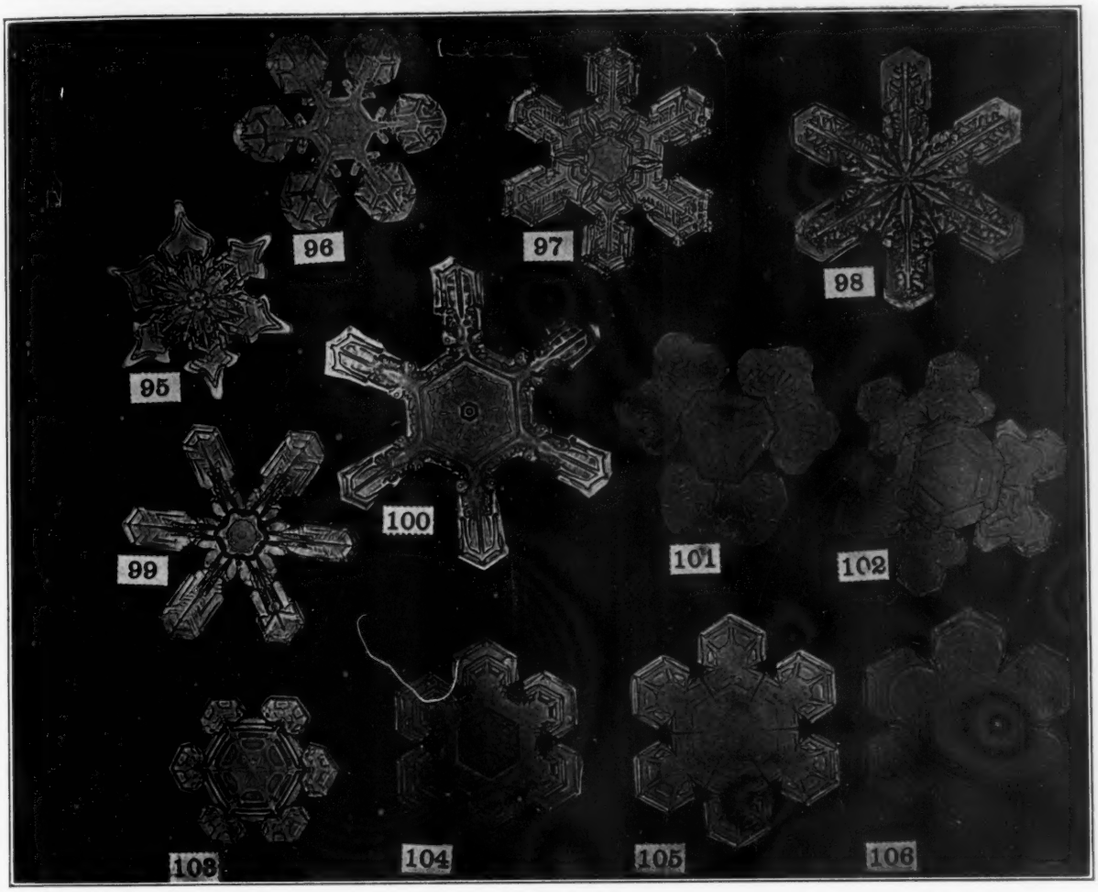
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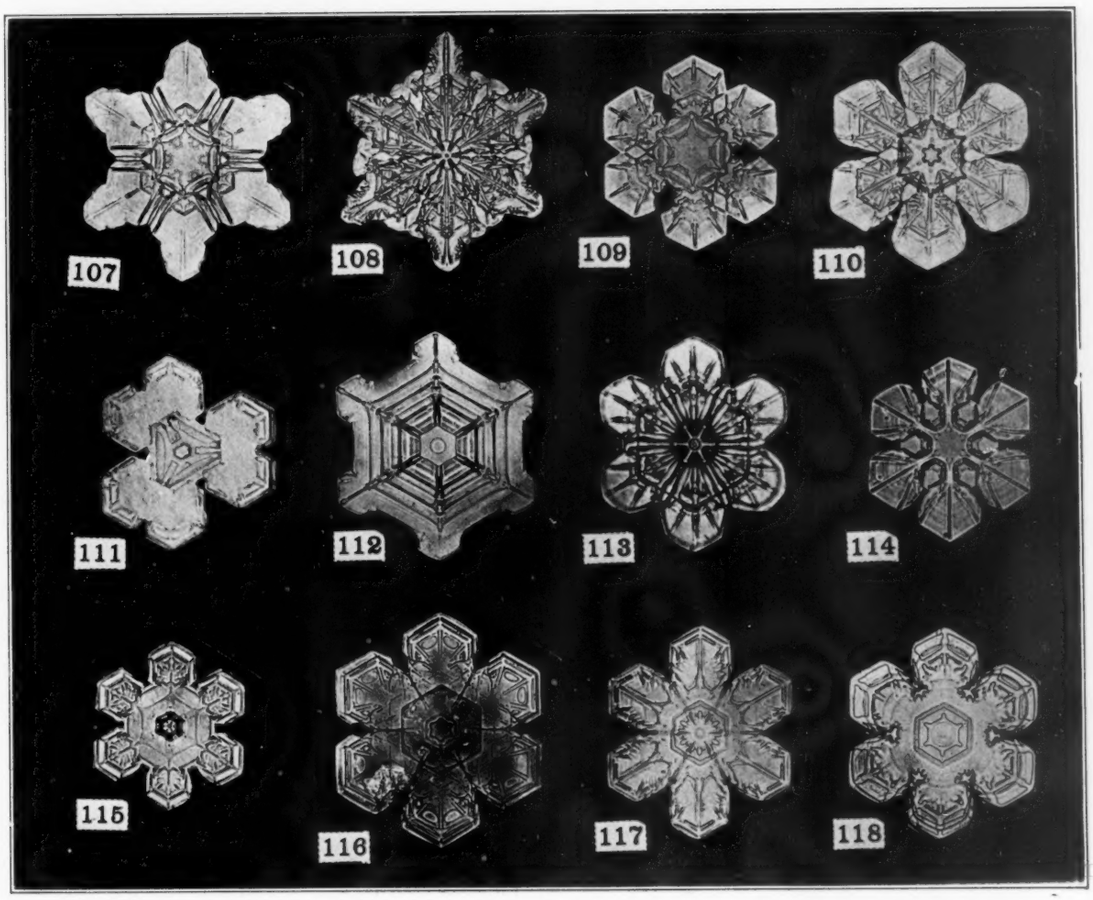
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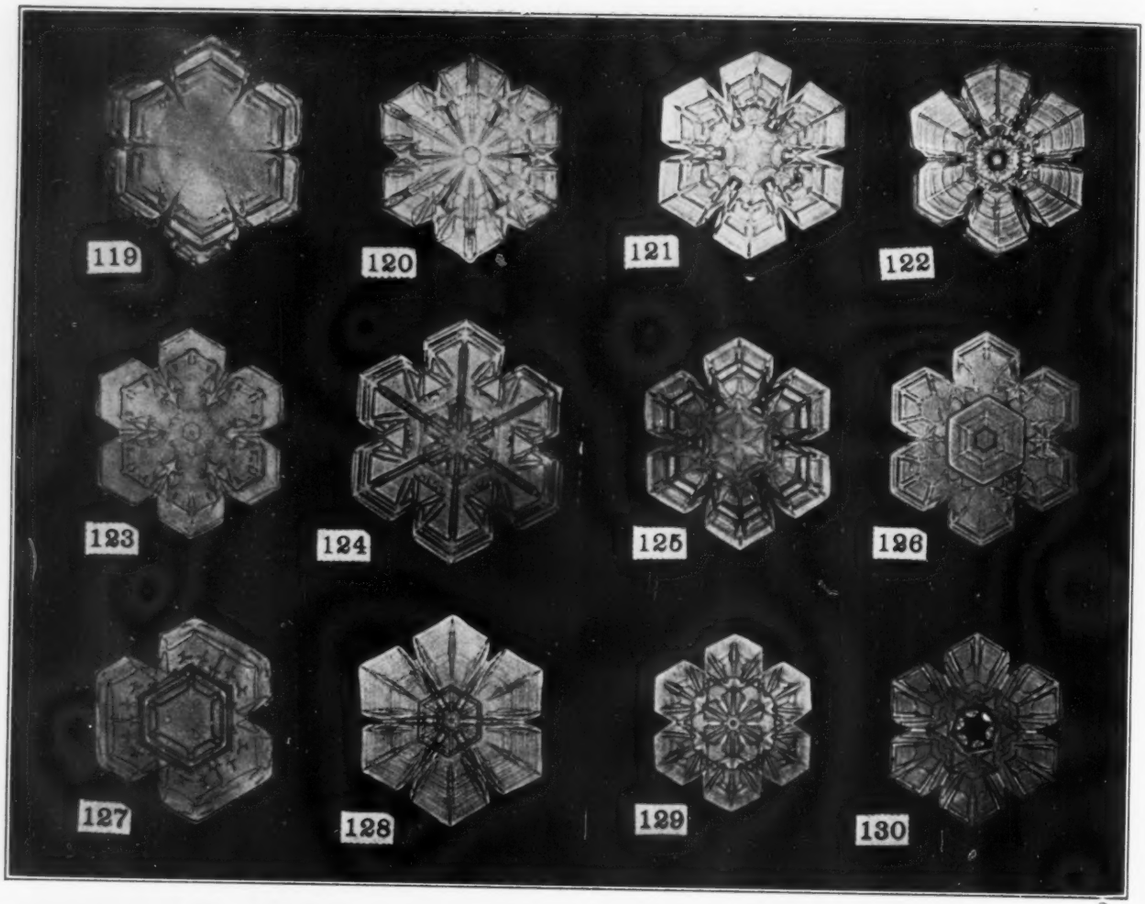
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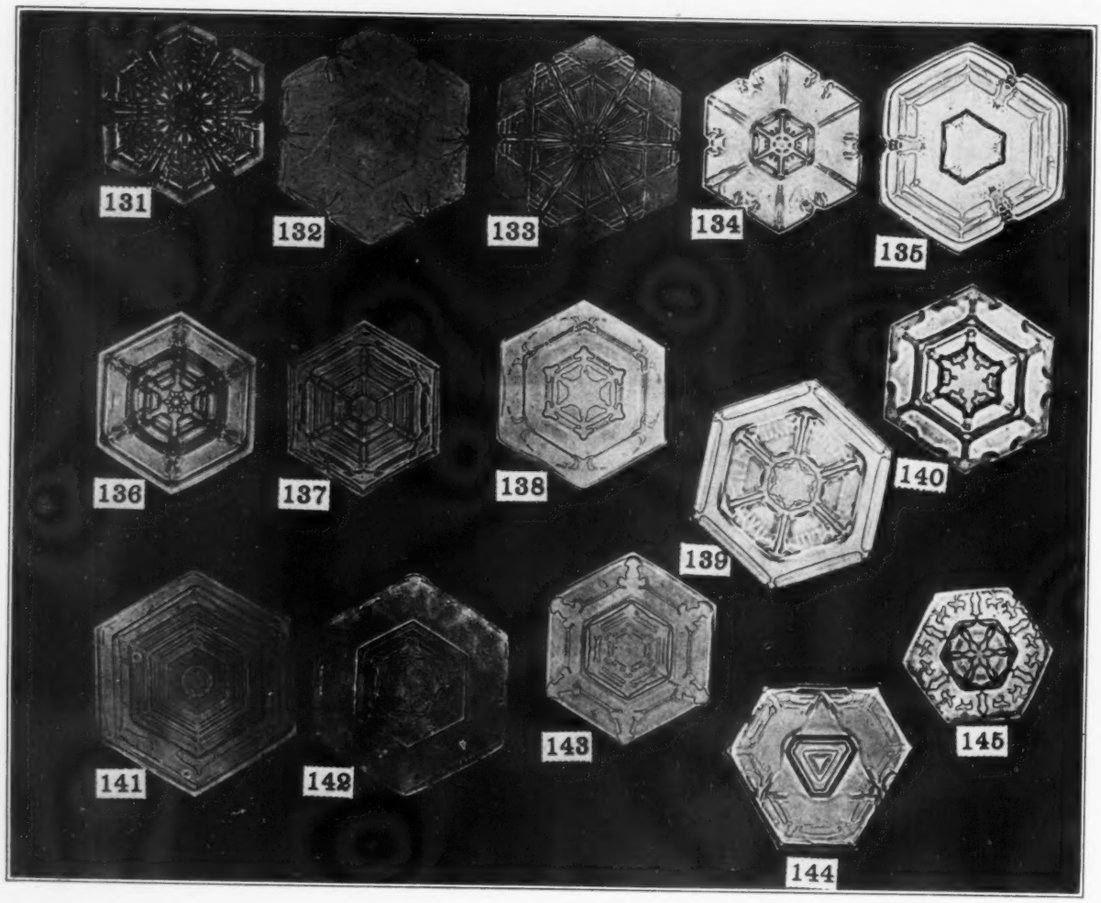
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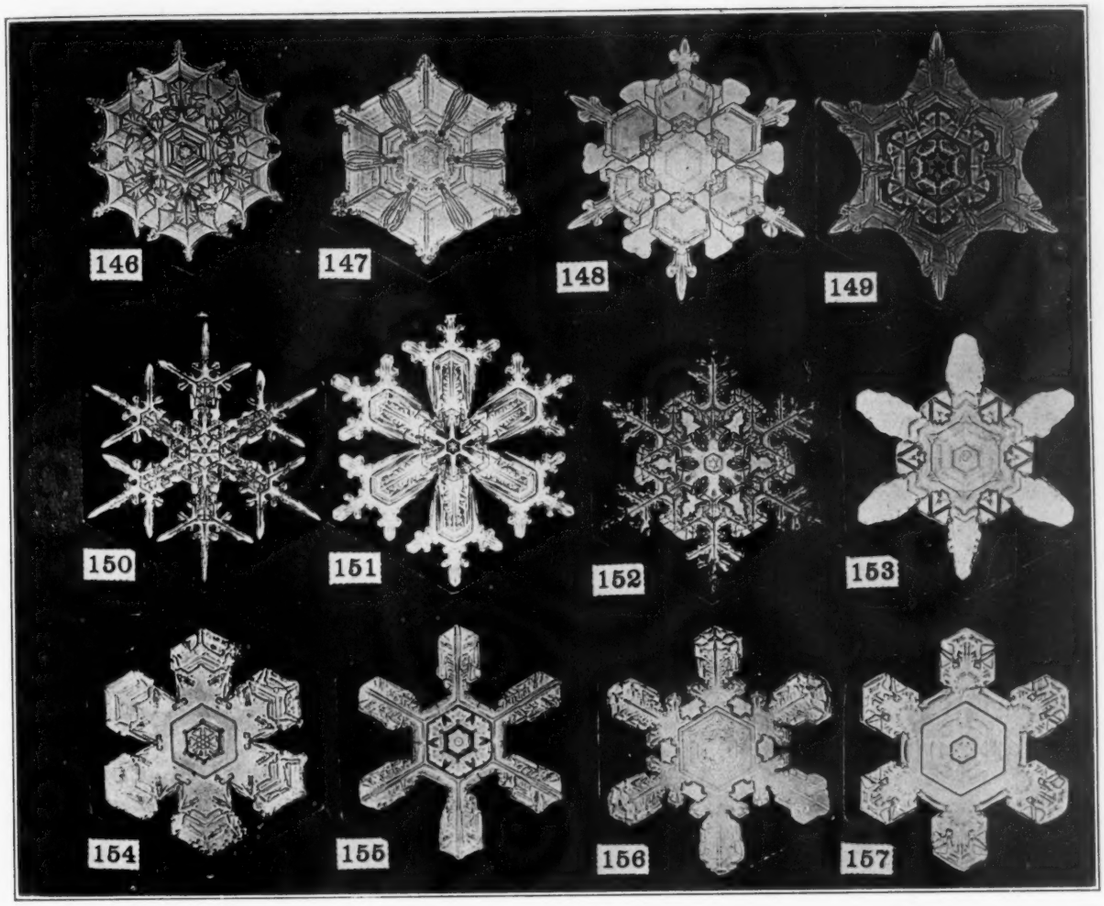
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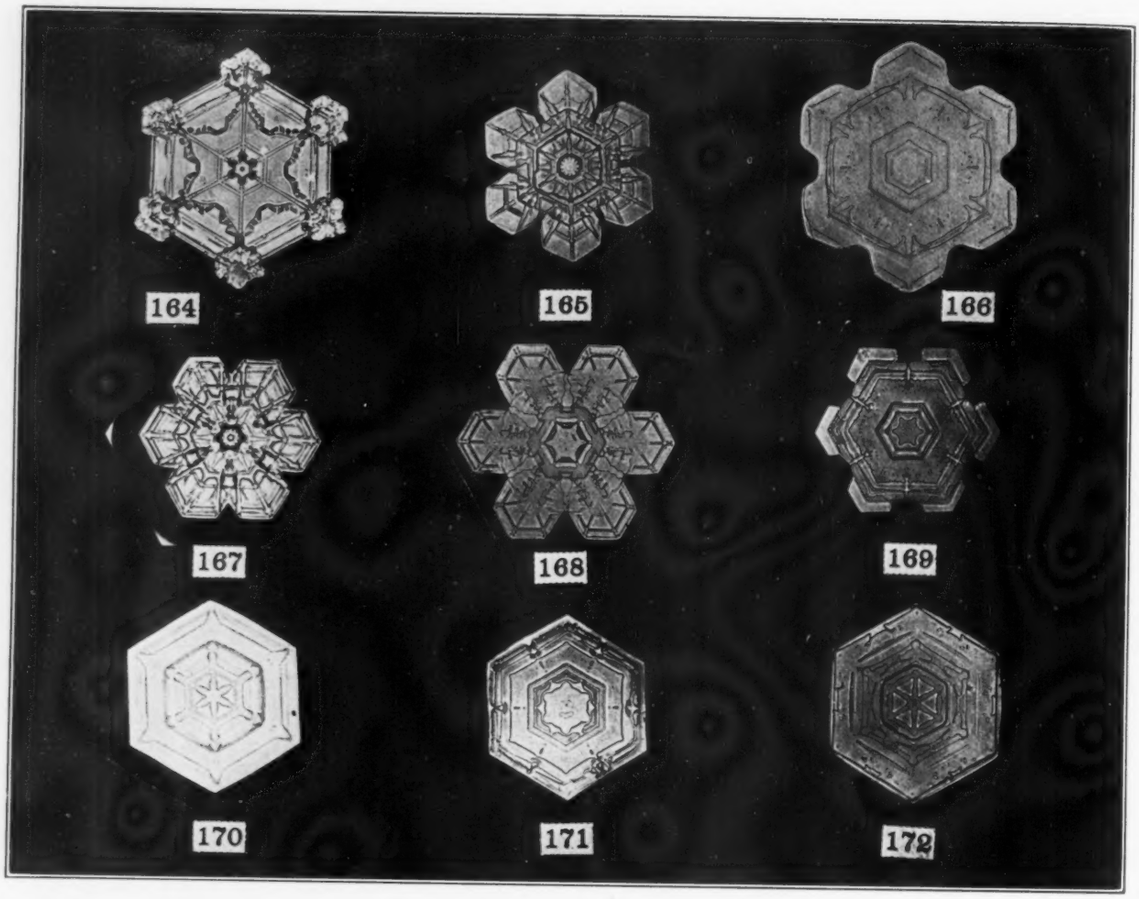
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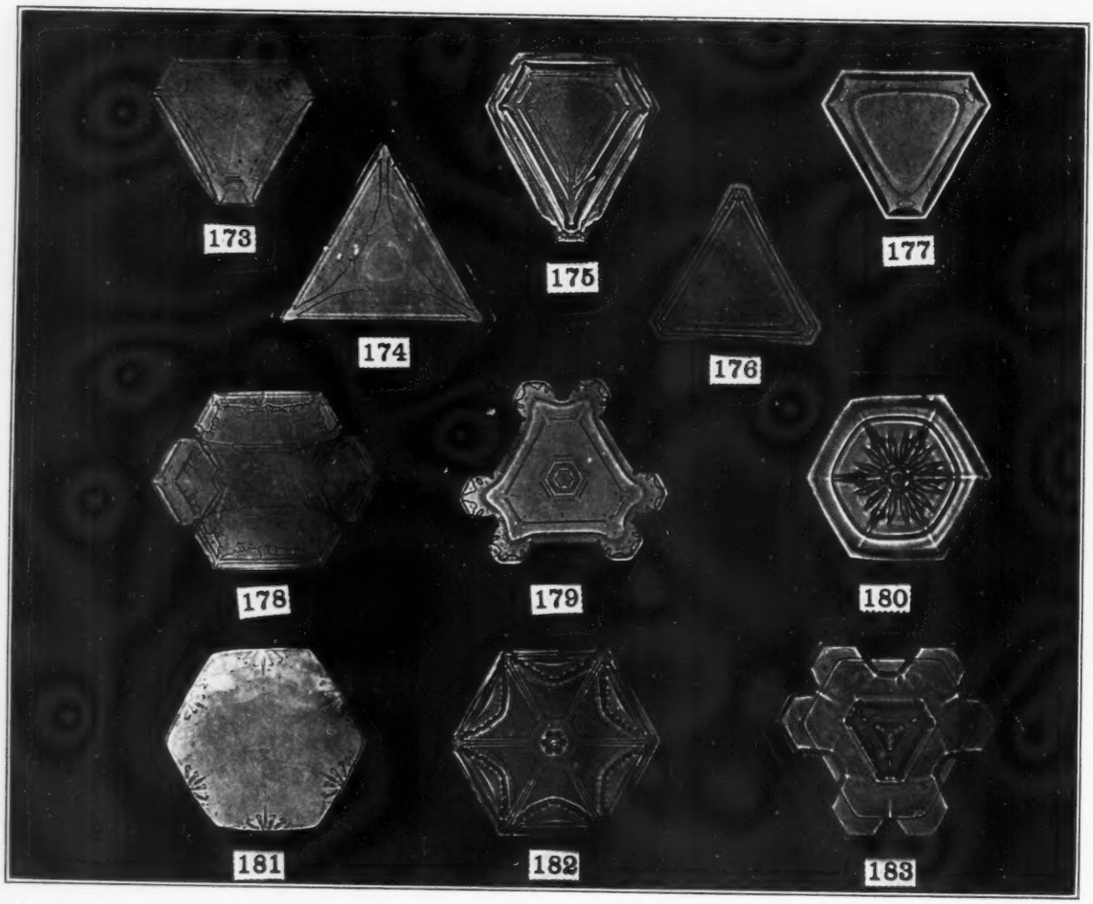
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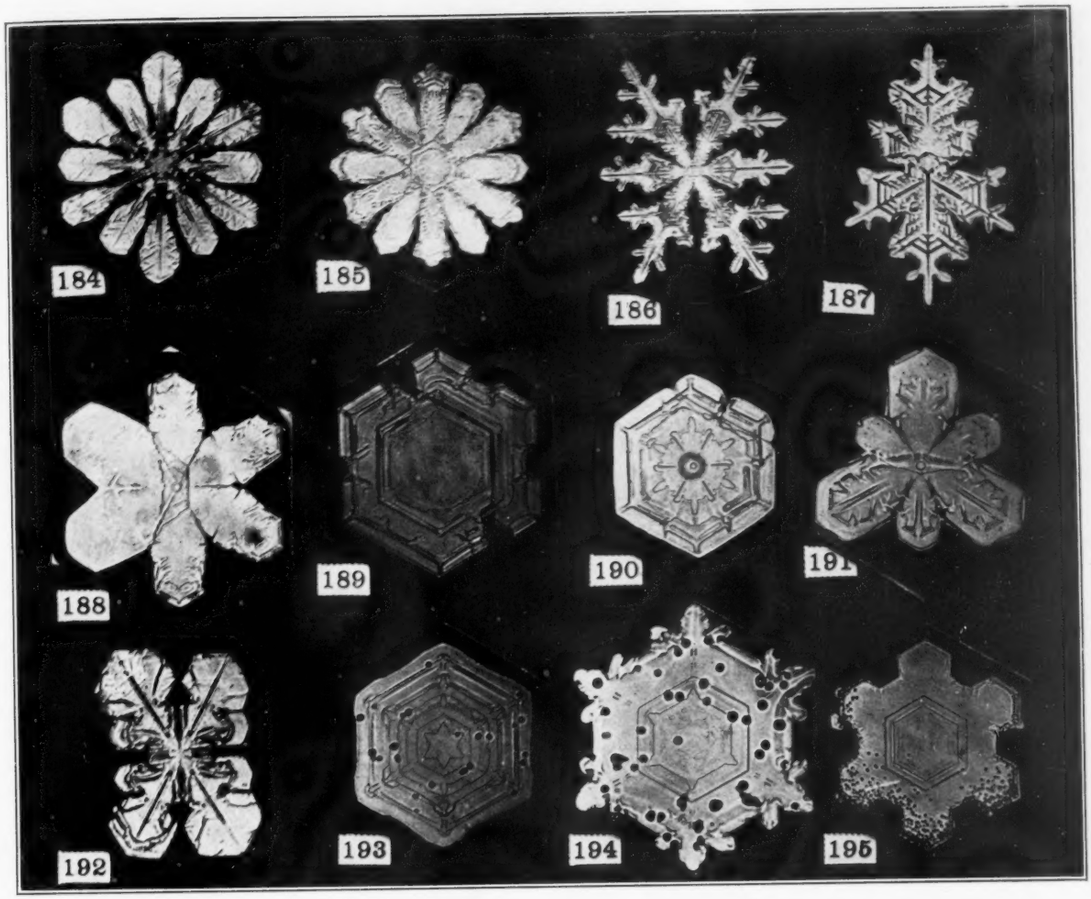
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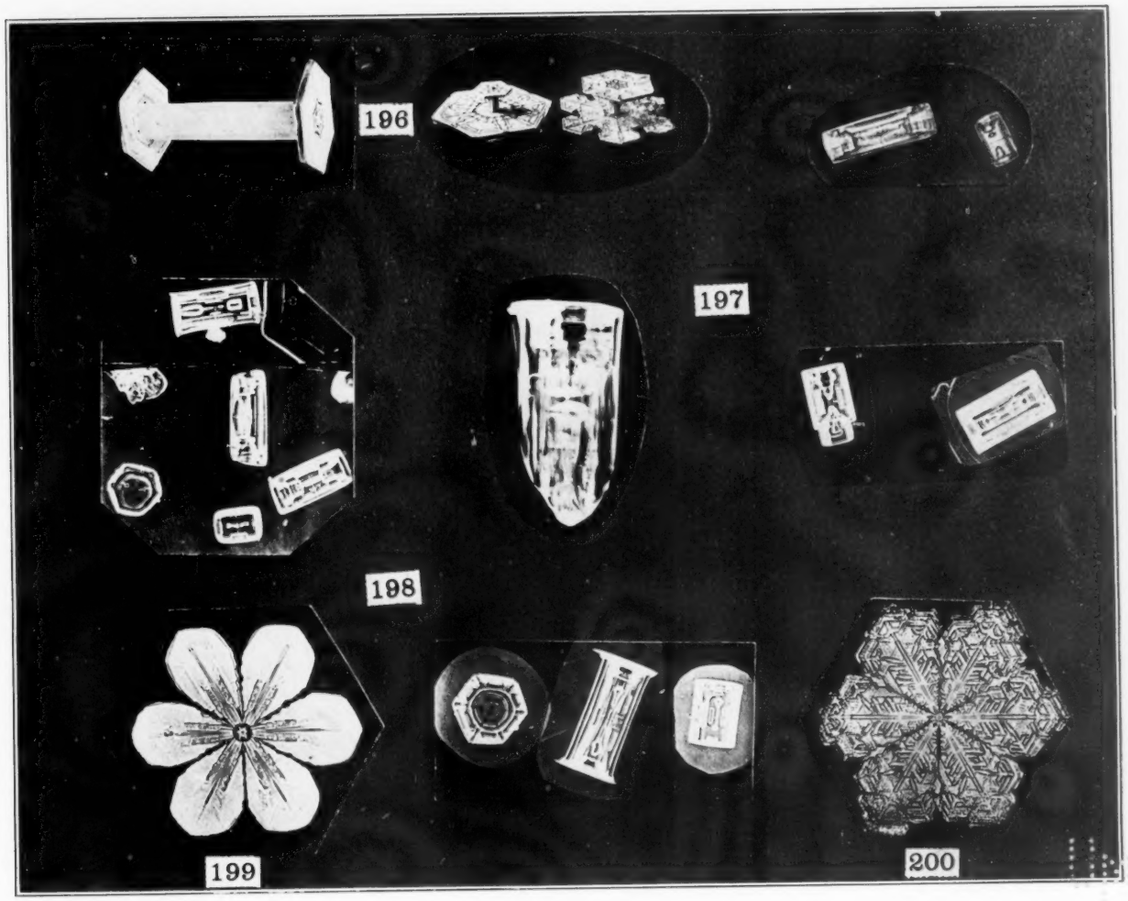
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THE SNOWFALL OF THE UNITED STATES.[1]

By Prof. ROBERT DEC. WARD.

(Abstract.)

THE ECONOMICS OF SNOW.

"The margin of temperature difference between rain and snow is a narrow one. It is, however, one of the most critical points in man's relation to the atmosphere, because of the fundamental differences in the economic effects of rain and snow. Snow, especially the deep snows which lie for weeks and months on the mountains and plateaus of the semiarid West, furnish a slower, and therefore a more lasting, natural supply of water for power, for irrigation, and for general use than does rain, which has a quick run-off. * * * A winter snow cover prevents deep freezing of the ground, protects grasses and fall-sown crops, and provides spring moisture for growing vegetation. * * *

"When sufficiently deep and more or less permanent, snow makes sleighing possible, and greatly facilitates lumbering operations over the forested sections of the northern and northeastern States. * * * Heavy winter snows, on the other hand, interfere with railroad operation, sometimes causing serious and expensive interruption of transportation, and involving great expense for the removal of snow from steam and electric railroads, and from city streets. At the same time, such conditions furnish employment to thousands of men. * * * The demand for all kinds of rubber footwear in the States where snowfall is a common winter characteristic has given rise to one of the important manufacturing industries of the snow belt. The use of snowshoes and skis, for winter sports as well as for ordinary means of locomotion, is another result of a winter snow cover.* * *

THE MEASUREMENT OF SNOWFALL.

"What is needed is careful determination both of the depth of snow as it falls and also of the water equivalent of the snow when melted." Methods and gages have been discussed in some detail in the MONTHLY WEATHER REVIEW, May, 1919, **47:** 294–296; and p. 697 below describes a new snow sampler.

"In the matter of forecasting the amount of water available from snow, the rate of melting of the snow, as well as the amount of evaporation from the snow fields and from the surfaces of water-storage basins are obviously of great consequence." In the high Sierras, when there are low temperatures and little wind movement, the average loss by evaporation is about three-quarters of an inch per day. Relatively high temperature, active wind movement, and abundance of strong sunshine result in a loss of freshly fallen snow which may average 10 inches a day, and of old snow, 3 to 4 inches.

An average annual snowfall map of the United States prepared in 1912 by C. F. Brooks from observations at about 2,000 stations during the 15 winters, 1895–1910, is reproduced.[2] The map published as Chart J. B. K. XVII in this issue of the MONTHLY WEATHER REVIEW was originally prepared by J. B. Kincer from all available records in the western mountains and from the complete records east of the Rockies, for the period 1895–1914. Then it was revised slightly to bring it into conformity with certain obvious topographic influences, and the detailed maps of United States east of the Mississippi, 1895–1913,[3] and of New England, 1895–1916,[4] without, however, getting away from the basic averages for the 20-year period.

GENERAL CONDITIONS OF SNOWFALL.

"The major controls of snowfall in the United States are the temperature, the season of precipitation, the frequency and intensity of winter storms, the topography, the proximity to primary sources of moisture supply, such as the oceans and the Great Lakes, and exposure to damp winds. * * * Over nearly all of the eastern United States the northeast wind, being both cold and damp, is the chief snow bringer. A 'northeast snowstorm' is a familiar winter characteristic, especially along the Atlantic coast. * * * The heaviest snows usually come in February or even in March over the northern sections. The northwest winds, blowing on the rear of the storms, are plenty cold enough to give snow, but are generally too dry. Snow flurries, rather than deep and general snows, are therefore usually associated with them. Exceptions must, however, be made in the case of windward mountain slopes, as in the Appalachian area, and of places to leeward of the Great Lakes, where the northwest winds may bring heavy snowfalls."[5]

With these general controls in mind the distribution of snowfall is easily to be remembered. The limiting latitudes of regular and of occasional snowfall may be broadly generalized as follows:

Latitudes of general and of occasional snowfall.

District.	Regular.	Occasional.
Pacific coast	45° (Northern Oregon)	34° (Los Angeles).
Interior	30° (Northern Gulf)	26° (southeast Texas).
Atlantic coast	35° (Hatteras)	29° (northern Gulf).

"From a practical point of view it may be said that snow does not occur in sufficient amount to lie unmelted on the ground south of San Francisco on the lowlands of the Pacific coast, or south of Cape Hatteras on the Atlantic coast. This statement, however, does not hold for inland districts, or for elevated areas. The southern boundary of a regular winter snow cover, in ordinary winters, may be put at about latitudes 41°–42° in the eastern United States, but occasional winters carry the snow cover a good deal farther south. It is one of the marked climatic characteristics of the eastern United States that snow not infrequently occurs unusually far south, in districts which have very mild winters. * * *

"The most striking general facts on the snowfall map are the effects of the topography in causing very heavy snowfalls on the western flanks of the Sierra Nevada and Cascade Ranges (exceeding 400 inches over considerable areas); the 'snow-shadow' effect of this western mountain barrier in causing a decrease in the depths of snowfall over the interior plateau districts as a whole, with larger amounts over the mountains and higher plateaus; the heavy snows of the Rocky Mountain system, averaging considerably less than on the Pacific coast mountains, but amounting to more than 100 inches over fairly large areas even as far south as northern New Mexico, reaching over 300 inches in southern Wyoming and 400 inches in

[1] *The Scientific Monthly*, Nov., 1919, vol. 9, pp. 397–415, map.
[2] First published in Quart. Jour. Roy. Meteorological Soc., Apr., 1913, vol. 39.
[3] C. F. Brooks, MONTHLY WEATHER REVIEW, Jan., 1915, **43:** chart 23.
[4] C. F. Brooks, ibid., June, 1917, **45,** fig. 30, p. 285.
[5] See articles with maps by C. F. Brooks, MONTHLY WEATHER REVIEW; 1914, **42:** 318–330; 1915, **43:** 2–11; 1917, **45:** 271–285.

parts of the Colorado Rockies. East of the Continental Divide the snowfall rapidly decreases again, the lines of equal depth extending in a general east-and-west direction under the control of latitude. The Appalachian mountains and plateaus carry the lines well to the south (50–100 inches from Maine to Maryland), while the warm waters of the Gulf Stream carry them northward along the coast as far as Cape Hatteras. In the vicinity of the Great Lakes, especially on their lee shores, and thence eastward along the Canadian boundary as far as New England, there is a relatively heavy snowfall (more than 100 inches in northern New England, and 80 to more than 100 inches on the lee shores of the Lakes). Excluding

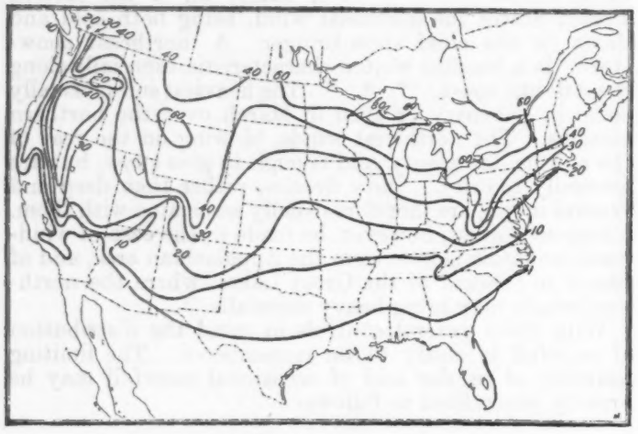


FIG. 1.—Average annual number of days with snow cover, 1895–1914.

the higher altitudes, the annual snowfall may be said to average roughly more than 20 inches over northern and less than 20 inches over southern sections. Most of this snow falls from December to March, but at the higher elevations, and in the northern States, it begins as early as October or even September, and falls as late as April or even May. In general, topography is seen to be the most striking control in the west, and latitude in the east."

SLEET AND ICE STORMS.

"Sleet and ice storms are so closely associated with snowstorms in the eastern United States that it is often difficult to forecast snow because a storm of sleet or ice may occur instead. Telegraph, telephone, and trolley wires, trees, sidewalks and streets are then covered with an icy coating. Service is thus often interrupted because of broken wires, and transportation becomes difficult or dangerous by reason of slippery rails and streets. Considerable damage is often done to forest and fruit trees by such ice storms. * * *

"The region of maximum frequency is over a broad central belt reaching from west of the Mississippi eastward and northeastward to the Atlantic. This is, in general, the portion of the country which is crossed by the principal storm areas, with their cold northerly winds to the north and warm southerly winds on the south of their centers. These conditions are essential to sleet formation. Severe sleet storms may occur from November to March, inclusive, and occasionally in April and October to the north of the 42d parallel. It appears that steep northward temperature gradients, and high temperatures over the Gulf and South Atlantic States are necessary for sleet formation, and are usually absent before and during heavy snowstorms. * * *"

A map of average annual number of days with snow cover, 1895–1914, by J. B. Kincer is reproduced as fig. 1, and one of days with snowfall, as fig. 2.

IS SNOWFALL DECREASING?

"There is a widespread popular belief in many parts of the country, especially in the earlier settled sections of the northeast, that less snow falls now than was the case years ago. In New England, for example, it is customary to speak of the 'old-fashioned New England winters' which brought many heavy snowstorms; when snow lay

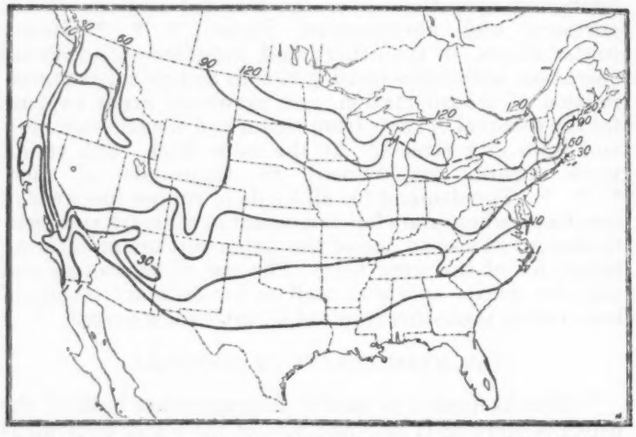


FIG. 2.—Average annual number of days with measurable snowfall, 1895–1914.

on the ground uninterruptedly all winter, and when sleighing was possible for three or four months without a break."[6] Impressions of snowstorms gained in childhood, particularly in the country, will not be equaled by those gained in adult life, especially if it is spent in a city. Great storms of history appear close together, just as telegraph poles seem to stand close together when we look back at them, but are some distance apart as they go by.[7]

Prof. Ward has done good service in presenting such an interesting summary of the subject, especially since it is so complete bibliographically. Half the references are to articles published in the MONTHLY WEATHER REVIEW since 1914.—*C. F. B.*

[6] Nevertheless, the winter of 1915-16 was in much of New England the equal of historic snowy ones. See "New England snowfalls" (C. F. Brooks), MONTHLY WEATHER REVIEW, June, 1917, 45:271–285, (30 figs.).—C. F. B.

[7] Centuries of history contain accounts of a number of snowy winters, but when the number of years is divided by the number of snowy winters, it is evident that a real "old-fashioned snowy winter" is to be experienced, on the average, only once in a lifetime.—C. F. B.

[To face p. 697.]

FIG. 1.—Snow tube and cutter assembled.

FIG. 2.—Photograph of cutter.

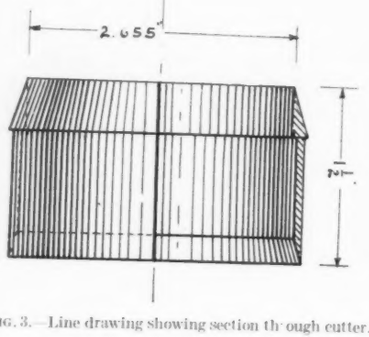


FIG. 3.—Line drawing showing section through cutter.

FIG. 4.—Weighing balance.

AN IMPROVED FORM OF SNOW SAMPLER.

By BENJAMIN C. KADEL.

[Dated: Weather Bureau, Washington, Dec. 3, 1919.]

Observations of the whole snow layer deduced from weighed sample sections have been made more or less generally in the Weather Bureau since the first introduction in 1905 by Dr. Frankenfeld of a form of sampler designed by Horton. The forms heretofore described are as follows:

1. The sampler designed by C. F. Marvin and described in Circular E, Instrument Division, Weather Bureau, page 31. The cutter proper is a piece of iron tubing several inches long, with inner diameter 2.65 inches, the lower edge being beveled and serrated in saw-tooth fashion. The main tube is of well-made tinners' spout about 4 feet long.

2. The sampler designed by Prof. J. E. Church, jr., is made of long narrow tubing, in separable sections, with smooth edged cutter 1.5 inches diameter. Length can be made 21 feet. (Described in Scientific American Supplement, Sept. 7, 1912, p. 152–155.)

3. The sampler designed by B. C. Kadel, and described in MONTHLY WEATHER REVIEW, May, 1915, **43:** 221, was of large diameter, 5.94 inches, and was equipped with an auger to be screwed down through the snow to form a bottom so that sample and tube could be withdrawn together.

The improved sampler now to be described was designed by the writer with a view to including such features as his own experience in snow surveying had suggested, and at various stages of its development was sent to the snow fields for actual trial. Suggestions made by the men who used the several experimental forms have been incorporated, as far as practicable, and desirable features of those above mentioned have been retained.

There are three parts to the device: the tube for holding the sample while it is being weighed; the cutter for bounding the area of the sample; and the spring balance.

The main body of the sampler (fig. 1) is of 3-inch drawn steel tubing, 20-gauge wall, in integral lengths varying from 2 feet to 6 feet, according to the depth of snow prevailing in the vicinity, several lengths being advantageous at some stations. No practicable means of joining two lengths has appeared, and while the tubing can be manufactured in 10-foot lengths, it is doubtful whether greater lengths than 6 feet can be successfully handled in the field. The instrument is intended for surveying such snow layers as are found over wide areas, rather than for the deep drifts of the timber line region. Longitudinal slots about $\frac{3}{16}$ inch wide by 8 inches long are cut on alternate sides to permit cleaning out the snow in case of sticking. The tubes have inch graduations and appropriate numbers to show snow depth, and after having been made up they are finished by sherardizing, a process resembling galvanizing, but leaving a smooth finish that does not destroy the etched graduations as would galvanizing, and furthermore offers less resistance to the free movement of the snow core through the tube because it is smooth. Observers report that oil or lacquer applied to the inner surface is an additional help. During the war, manufacturers were unable to supply the special tubing, and we had to substitute galvanized iron tinners' down spouting, 3-inch by 24-gauge, with a graduated metal tape riveted in place longitudinally.

The cutter (figs. 2 and 3) with its special shape, constitutes an extremely important part of the device. The inside diameter is turned true to 2.655 inches, which makes one-fifth of a pound of snow equal to 1 inch water equivalent, this relation being selected for convenience in calibrating the spring balance. The diameter selected is the result of a number of carefully made experiments in the field, which showed that cutters of too small diameter take up a sample that is too small to be representative of the layer from which it is cut, while samplers of larger diameter, such as described under No. 3, are too large and clumsy for use, particularly when they must be transported on snowshoes, although they possess the advantage of giving precise results. An examination of the illustrations will show that the cutter is sharply shouldered off at a point $\frac{1}{2}$ inch above its cutting edge. This shoulder is found in practice to wedge the snow so that in the great majority of cases the entire core can be withdrawn without losing the sample; although in some instances of extremely light, dry snow, observers report that it is necessary to tamp the snow into the bottom of the tube by means of a long slender stick, in order that it may be somewhat packed before the tube is withdrawn. The essential diameter of the cutter is practically the same as that of the Marvin cutter described under No. 1, but the difference between the diameter of the cutter and the diameter of the main tube has been made much greater, in order to allow ample clearance for the ascending snow core and thus avoid undue friction upon the walls of the tube, with resultant deficient pickup. The cutters have smooth edges and are made interchangeable, so that in case of damage a new one can be easily attached.

The spring balance (fig. 4) as shown in the illustration has grown out of experience. The graduations, which are engraved directly upon the case of the spring balance, give inches and tenths of water equivalent direct. The indicating hand is rigidly pinned to its arbor, thus eliminating the chance of accidental displacement. The bent aluminum wires are intended to hold the filled tube in a horizontal position for weighing, while the hook at the top is intended to be placed across a limb of a tree or other means of support. The entire balance is built of aluminum for lightness.

The spring balances have been specially constructed for us by John Chatillon & Sons, New York. The tubes and cutters have been made up in the Weather Bureau shop. A blueprint can be supplied to anyone who wishes to construct a sampler. Valuable suggestions and assistance have been given by my colleagues in the Insrument Division.

SNOW AND RAILWAY TRANSPORTATION.

By ANDREW H. PALMER, Meteorologist.

[Dated: Weather Bureau, San Francisco, Calif., July 22, 1919.]

Throughout the northern part of the United States, snow is a costly impediment to transportation during several months of every winter. In great cities like New York, Chicago, and Boston, the cost of snow removal from the streets amounts to hundreds of thousands of dollars per annum. Records of the New York City street cleaning department show that in the winter of 1916–17 the cost of removing snow and ice from the streets of New York City was $1,127,018, while in the winter of 1917–18 it was $2,676,603. In all northern cities street railways find this inevitable item of expense is of large proportions. When the Weather Bureau makes a forecast of snow in Boston, the Boston Elevated Railroad, which operates most of the street cars in that city, holds several hundred reserve men in readiness for immediate duty, both during the day and at night. In the case of steam railroads the snow problem is one of prime importance, and it has received the attention of leading engineers.

The amount of snowfall varies greatly in different parts of the United States, and the conditions under which it falls also vary. For this reason different railroads attack the problem differently. In many parts of the eastern United States most of the railroads each autumn put up wooden fences, 4 to 6 feet in height. These are built in sections. The fence consists of wooden boards nailed 3 or 4 inches apart to heavy wooden posts. The fence is necessary usually only on the west or north side of the track, as drifting snow is carried mostly by northerly or westerly winds. By breaking the force of the wind near the ground it causes the snow to be precipitated in a drift on the leeward side of the fence, leaving the track beyond relatively clear. This costly construction is necessary for many miles on the open prairies.

Some railroads of the plains States have recently planted rows of trees for windbreaks. Those species of trees were selected which are of hardy constitution and which grow rapidly. The experiment proved so successful that during the summers of 1917 and 1918 many miles of young trees were planted in this manner. They were placed close together, and a few years hence they will form a barrier which will break the force of the driving snow-bearing winds and cause the snow to be deposited at the bases of the trees, leaving the track clear.

During the summer of 1916 the Union Pacific Railroad made various shortenings of its transcontinental routes in Colorado and Wyoming. In doing so several new gulches and canyons were created along the right of way. The following winter, that of 1916–17, proved to be one of abundant snowfall in the Rockies, and the driving winds soon filled these gulches after each snowstorm. Tie-ups resulted, each lasting several days. Transcontinental trains were delayed, and San Francisco and Los Angeles received no eastern mail for three to five days on each occasion. Steamers about to sail for the Orient delayed their departures in order to await the arrival of passengers and mail en route from the East. During the following summer windbreaks consisting of young trees were placed at appropriate places above the canyons, and eventually, it is hoped, trouble due to snow blockades will largely be eliminated.

The railroads which cross the Cascade Mountains of Washington and Oregon and the Sierra Nevada of California have to contend with a snow problem of great difficulty. In these mountains, where the snowfall is the heaviest in the United States, snow accumulates on level ground to a depth of 25 to 30 feet, and depths twice as great may be found in canyons and gulches.[1] In the high Sierra Nevada of California accurate records kept by cooperative observers of the Weather Bureau show that at certain places a snowfall of 60 to 65 feet in one winter is not uncommon. The greatest snowfall in the United States is that at Tamarack, Alpine County, Calif., altitude 8,000 feet, where 884 inches, or 73.7 feet, of snow fell during the winter of 1906–7.[2]

When snow on level ground accumulates to depths of a few feet, it is the custom of the railroads to remove the snow from the track by means of a locomotive push plow, as is shown in fig. 1, or by means of a rotary plow, as shown in fig. 2. It is not unusual for a locomotive to come into the roundhouse with the appearance of the one shown in fig. 3. The cleared tracks through a typical western railroad town are shown in figs. 4 and 5. In all exposed tracks the source of most troubles caused by snow is that of the blocking and the freezing of switches, signal apparatus, and turntables. To keep these open requires considerable hand labor. (See figs. 6 and 7.)

When snow on level ground accumulates to a depth of 25 to 30 feet, and perhaps twice that depth in canyons and gulches, it is apparent that its removal is impossible. The problem was solved by the engineers in charge of the construction of the Central Pacific Railroad, now the Overland Route of the Southern Pacific. In crossing the Sierra Nevada, this railroad climbs from 71 feet at Sacramento, Calif., to 7,017 feet at Summit, Calif., and descends to 4,532 feet at Reno, Nev. In order to operate during the winter months it was found necessary to construct 32 miles of snowsheds between Blue Canyon and Truckee, at a cost of $42,000 a mile over single track and $65,000 a mile over double track. (See figs. 8, 9, 10, and 11.) On an average, $150,000 a year is spent for upkeep and renewals, the expenditure for a typical year, 1914, having been $65,000 for repairs and $91,000 for renewals. The average life of a shed is 22 years. The sheds are built of massive timbers and are designed to sustain snow 16 feet in depth. When the snow gets deeper than 16 feet it must be shoveled off by hand. At certain points where the railway is located along steep slopes, thousands of tons of snow slide over the tops of the sheds each winter. At these places a kind of apron, technically known as a "backoff," 30 to 40 feet in length, is built on the upslope side of the shed in order that the snow may slide harmlessly over the top. Even though timbers 12 inches by 14 inches in cross section were used in its construction, 48 feet of snowshed near Blue Canyon collapsed because of the weight of snow, on February 15, 1915. The fire hazard in these sheds, naturally, is great. For fire-fighting apparatus four trains in summer and two trains in winter are kept under constant steam. All local engines carry pumps, and are followed by tank cars filled with water for fire-fighting purposes. The locomotives used on this mountain division are of massive construction, and are the most powerful in California. (See fig. 12.) Concrete snowsheds have been built on other railroads to offset the

[1] Palmer, Andrew H., "The Region of Greatest Snowfall in the United States." MONTHLY WEATHER REVIEW, vol. 43, May, 1915, pp. 217-221.

[2] Compare, however, Fisher, Lawrence C., "Snowfall on Mount Ranier, Washington." MONTHLY WEATHER REVIEW, vol. 46, July, 1918, pp. 327-330. At Paradise Inn in the winter of 1916–17, the only winter snowfall which was observed there, the total exceeded 789.5 inches.

FIG. 1.—A locomotive push plow at work in the region of greatest snowfall. (Photograph by Fred Rath.)

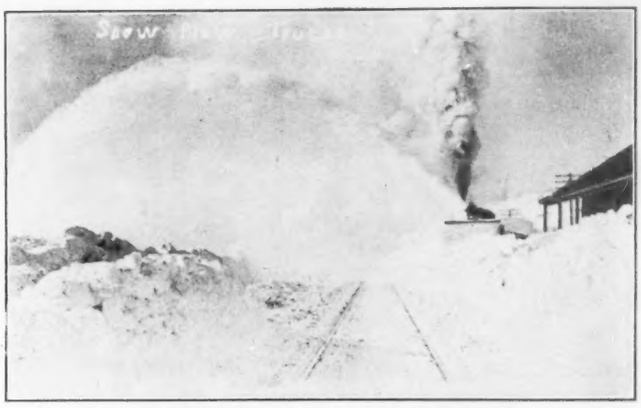


FIG. 2.—A rotary snowplow at work on the Southern Pacific at Truckee, Calif.

FIG. 3.—A Southern Pacific locomotive at the end of a winter run.

FIG. 4.—Cleared tracks on the Southern Pacific at Blue Canyon, Calif. (Photograph by W. E. Banbrook.)

FIG. 5.—Cleared tracks on the Southern Pacific near Emigrant Gap, Calif. (Photograph by Fred Rath.)

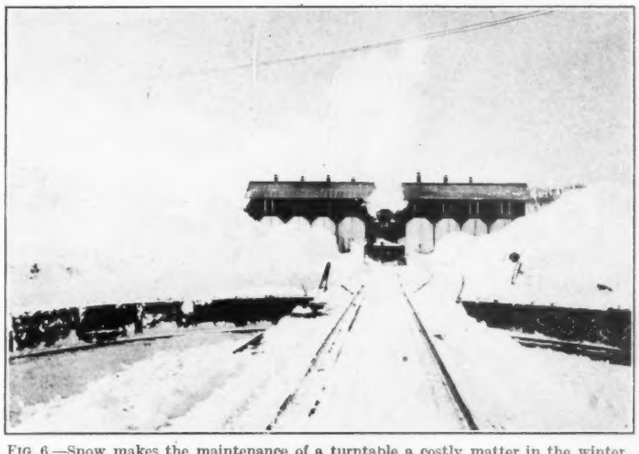


FIG. 6.—Snow makes the maintenance of a turntable a costly matter in the winter. (Photograph by Fred Rath.)

FIG. 7.—Railroad snowsheds in the high Sierra Nevada Mountains of California.

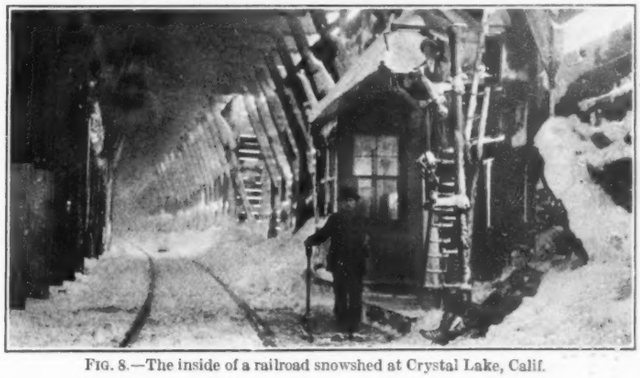


FIG. 8.—The inside of a railroad snowshed at Crystal Lake, Calif.

fire hazard, but their initial cost renders that form of construction almost prohibitive.

Besides actually impeding traffic, snow is sometimes a costly factor in operation in that it occasionally causes destructive slides. These slides not only sweep away the snowsheds but sometimes occur during the passage of a train, with resultant disaster. On January 22, 1916, a snowslide struck an all-steel passenger train near Corea, Washington, cutting it in two, and sweeping several coaches into a ravine 120 feet below, with resultant loss of several lives. In order to combat the hazard of snowslides the U. S. Weather Bureau has studied the conditions under which they occur. During the season when there is danger from such slides, warnings are issued to proceed cautiously, and in some instances train dispatchers have stopped the movement of trains until the danger has passed.

While the recurring snows of winter are a great benefit to agriculture, both as a source of moisture and as a protective blanket to submerged vegetation, they are a costly impediment to railway transportation. In severe winters, like that of 1917–18, the delay to transportation caused by excessive snowfall sometimes affects business in general. Occasionally it causes real peril, through the delay resulting in the delivery of food and fuel. Automobile trucks are already an important factor in the transportation of freight and express matter between adjacent cities and towns. These too are impeded by deep snow to such an extent that service must occasionally be abandoned for brief intervals during the winter half-year.

In an article entitled, "Millions Saved on Mild Winter,"[3] published in the New York Times, April 6, 1919 (sec. 2, p. 2), it is stated that in an average winter the cost to the railroads of the United States for removing snow and ice from the tracks is between $5,000,000 and $6,000,000. In a severe winter it may cost much more. For example, in the remarkable winter of 1917–18 the cost was between $7,000,000 and $8,000,000. In a mild winter the cost may be much below the average. An eastern railroad official estimated that in a mild winter the cost may be 25 per cent below the average figures given above, while in an extremely mild winter, like that of 1918–19, there may be a saving of fully 50 per cent of the figures given.

While a heavy snowfall adds greatly to the cost of maintenance of way, it also causes loss through interrupting the flow of freight, and eventually to business and industry in general. Furthermore, when coal arrives at its destination solidly frozen in cars which have to be thawed out, further delay and increased costs are unavoidable. For these reasons the general character of a winter is often reflected by the cost of operation figures appearing in the reports of the railroads of the northern portion of the United States.

[3] Abstract of this article appears in MONTHLY WEATHER REVIEW, vol. 47, March, 1919, p. 170-171.

SNOWFALL AND SNOW COVER ON THE ST. BERNARD ROAD (ENTREMONT VALLEY) IN WALLIS, FROM 1904 TO 1913.

By P. L. MERCANTON.

(Abstracted from Meteorologische Zeitschrift, Nov.-Dec., 1918, pp. 269-272.)

By means of measures made during the winters from 1904 to 1913, by postal-service men and others passing along the road, it has been possible to obtain mean values of the snowfall and snow cover during the winter months. These measures were made at the first and the middle of the months, by noting the snow depth on graduated telegraph poles along the road. The following table is presented:

STATION OF ORSIERES (alt. 970 meters).

	Nov. 1.	Dec. 1.	Jan. 1.	Feb. 1.	Mar. 1.	Apr. 1.	May 1.	June 1.
	cm.	cm.	cm.	cm.	cm.	cm.	cm.	cm.
Snowfall during previous month...	3	11	23	25	25	12	1	3
Snowfall since beginnmg of winter.	3	14	37	62	87	99	100	103
Snow cover, total.....	.....	10	13	14	18	1	0	0
Snow cover, monthly increase.....	.....	.....	+3	+1	+4	−17	−1	.....

STATION OF ST. PIERRE (alt. 1,630 meters).

Snowfall during previous month...	25	34	53	43	50	62	20	22
Snowfall since beginning of winter.	26	60	113	156	206	268	288	310
Snow cover, total.....	.....	23	27	31	52	28	0	0
Snow cover, monthly increase.....	.....	.....	+4	+4	+21	−24	−28	.....

STATION OF GREAT ST. BERNARD (alt. 2,230 meters).

Snowfall during previous month...	88	155	191	119	120	158	98	72
Snowfall since beginning of winter.	115	270	461	580	700	858	956	1,028
Snow cover, total.....	29	46	66	100	166	197	169	75
Snow cover, monthly increase.....	.....	+17	+20	+34	+66	+31	−37	−85

These figures show the maximum fall to be during December and January; the greatest depth of snow cover to be during March and April; the greatest increase of depth of snow cover during February. After the maximum depth is attained, however, it decreases rapdly during May and June. Naturally, the higher stations show greater intensities of snow, in respect to depth and amount.—*C. L. M.*

SNOW IN THE FRENCH ALPS.

By M. E. BENEVENT.

Abstract reprinted from Geogr. Review, April, 1919, p. 273. Article in Recueil des Trav. de l' Inst. de Geogr. Alpine, vol. 5, 1917, No. 4, pp. 403-497.]

The regimen of the snowfall is discussed in respect of quantity, frequency of precipitation, and duration of snow cover. In conclusion these factors are analyzed in their combined effect on human relation. The region naturally falls into two main subdivisions—the Northern Alps, whose precipitation is controlled by oceanic influence, and the Southern Alps, controlled by Mediterranean influence.

SNOW CONDITIONS AT GENEVA IN THE 60 YEARS 1857 TO 1917.

By RAOUL GAUTIER.

[From abstract by J. V. Hann, Meteorologische Zeitschrift, Jan.-Feb., 1918, pp. 44-46.]

This investigation concerns itself with the average depth of snow, the number of days of snow, and the length of time the snow remained on the ground. Of the mean for 60 years, we have for the average depth of snow, 42.4 cm.; for the average number of days of snowfall per year, 8.2; for the length of time of snow on the ground, 17.2 days. The maxima for these values, however, are 172 cm., 30 days, and 86 days, respectively. The exceptional years and unusual instances of snowfall are discussed in the latter part of the article.—*C. L. M.*

RELATION OF SNOWFALL TO THE YIELD OF WINTER WHEAT.

By CLARENCE J. ROOT, Meteorologist.

[Dated: Weather Bureau, Springfield, Ill., Oct. 22, 1919.]

The value of snow as a protective measure to winter wheat is a subject on which authorities do not agree, and the writer does not contend that the statements presented in this paper serve to offer a solution of the question, but the data may be of interest. There are many elements entering into the problem that make it quite complex. Among these are the distribution of the snow, both geographically and by time, the condition as to snow cover during periods of extreme cold, freezing and

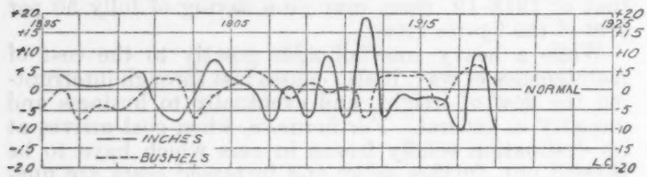


FIG. 1.—The departure of snowfall from the average, by winters for Illinois, in inches, and the departure of the yield of winter wheat for the following season from the average, for Illinois, in bushels.

thawing, rainfall or drought during the autumn and spring, excessive heat, insect pests, and plant diseases.

Omitting consideration of the above-named elements, diagrams have been prepared (figs. 1–4) showing the yields of winter wheat and the snowfall, mean and lowest winter temperatures in the preceding winters, with respect to the averages of these features for the period of record. The wheat data are furnished by the Bureau of Crop Estimates; the temperature and snowfall data

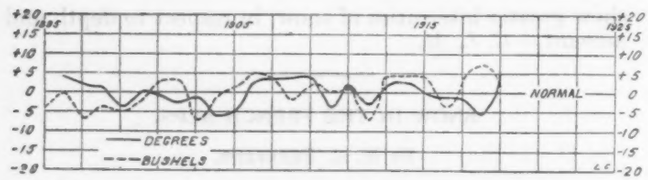


FIG. 2. The departure of mean temperature from the normal, by winters (December January, February), for Illinois, in degrees Fahrenheit, and the departure of the yield of winter wheat for the following season from the average, for Illinois, in bushels.

are compiled from the records of all meteorological stations in Illinois, numbering 86 at the present time.

A study of the diagrams shows that of the 13 years when the wheat yield was above the average, the snowfall of the previous winter was below the average in 10. Of these 10 winters the mean temperature was above normal in 6, and normal in 2. This indicates that, generally speaking, the best wheat years were preceded by winters with less than the normal snowfall, but that in most of those winters the temperature was normal or above.

Of the 9 years that the wheat yield was below normal, the snowfall of the previous winter was above normal in 7 and normal in 1. Of these 7 winters the mean temperature was below normal in 4. From this it will be seen that the winters of heavy snowfall have not as a rule been followed by large wheat yields.

The winter of the greatest snowfall, a cold winter, was followed by the poorest wheat yield but one. The

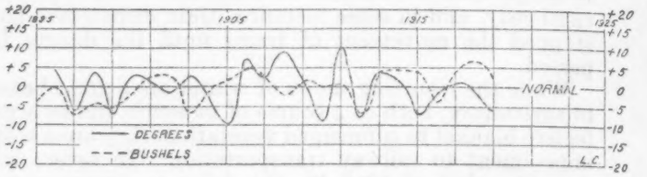


FIG. 3.—The departure of the absolute minimum temperature from the average by winters (December, January, February), for Illinois, in degrees Fahrenheit, and the departure of the yield of winter wheat for the following season from the average, for Illinois, in bushels.

winter of the least snowfall (1918–19), a mild winter, bid fair at the close of winter to be followed by a record wheat crop. In the early spring the crop was in a most excellent condition, but later disease and adverse weather conditions caused considerable deterioration.

The cold winters have heavy snowfall and the mild winters have light snowfall. This is due to the facts; (1) that during the mild winters much of the precipitation

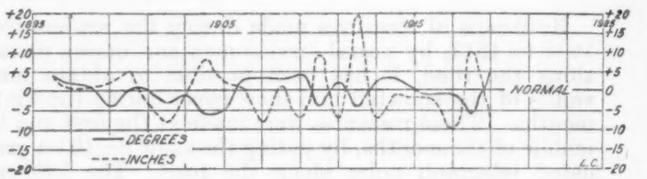


FIG. 4. The departure from the normal snowfall, by winters, for Illinois, in inches, any the departure from the normal mean temperature, by winters (December, January February), for Illinois, in degrees Fahrenheit.

falls as rain; and (2) that a snow-cover tends to make the surface air colder.[1]

Considering only the elements of total snowfall and mean temperature, it would appear that the winters of light snowfall are followed by good wheat yields, and the winters of heavy snowfall are followed by light yields. However, this may be due in part to the fact that the temperature is less severe in the winters of light snowfall.

[1] See MONTHLY WEATHER REVIEW, Dec., 1918, 46: 573–574.

EFFECT OF SNOW ON WINTER WHEAT IN OHIO.

By J. WARREN SMITH, Meteorologist.

[Dated Washington, D. C., December 3, 1919.]

SNOWFALL AND WINTER WHEAT.

A considerable fall of snow is generally thought to be favorable for winter grains, especially if it comes late in the spring. A correlation of the amount of snowfall with the yield of winter wheat in three counties in Ohio, as shown in Table 1, seems to controvert this idea and shows that a heavy snowfall in March is detrimental rather than beneficial.

TABLE 1.—*Correlation between snowfall and the yield of wheat, Ohio, 1892–1914.*

Month.	County.	Correlation coefficient.	Probable error.
January	Fulton	0.42	±0.13
February	do	0.12	±0.15
March	do	−0.84	±0.04
Do	Wayne	−0.69	±0.08
Do	Seneca	−0.48	±0.11

This indicates that in northwestern Ohio a heavy snowfall in January is slightly favorable; has little or no influence on the final yield if it comes in February, but a decidedly adverse influence if in March. This unfavorable influence of March snowfall in Fulton County is verified by the showing for Wayne and Senaca counties, both in Northern Ohio.

In fig. 1 the relation between the snowfall in March at Wauseon, Ohio, and the yield of wheat in Fulton County is indicated by the two lines. They show that in nearly every case when the snowfall was above the normal the yield of wheat was below the normal. In 1899 and 1912 especially, when the snowfall was unusually large, the wheat yield during each year was remarkably low. The figures at the left show variations from the average for both yield and snowfall.

In general, a month of heavy snowfall in Ohio is cooler than normal, while a warm March is accompanied by light snowfall. It has been shown [1] that a warm March is decidedly favorable for winter wheat in Ohio. The correlation coefficient between the average March temperature for the State of Ohio and the average yield of winter wheat for Ohio, covering a period of 60 years, is +0.46, with a probable error of ±0.06.

In view of the evident effect of March temperature and the relation between temperature and snowfall the point has been raised that the damaging effect of snowfall in March is more apparent than real and that it is due largely to cool weather.

To determine the real facts we have calculated the partial correlation for the three factors, temperature, snowfall, and wheat yield, as indicated in the following equations:

Let r_{sy} indicate the correlation coefficient for the March snowfall and wheat yield in Fulton County, Ohio, $= -0.84, \pm 0.04$.

Let r_{ty} indicate the correlation coefficient for March temperature and wheat yield in Fulton County, Ohio, $= +0.62, \pm 0.09$.

Let r_{st} represent the correlation coefficient for the March snowfall and temperature in Fulton County, $= -0.678, \pm 0.08$.

[1] Agricultural Meteorology, J. Warren Smith, President's Address, Proceedings of the Ohio Academy of Science, Vol. VI, Part 5.

To eliminate the effect of the temperature and show the influence of the snowfall alone the equation may be written:

$$(1) \qquad r_{sy.t} = \frac{r_{sy} - r_{st}\, r_{ty}}{\sqrt{(1-r_{st}^2)\,(1-r_{ty}^2)}}$$

Inserting the various correlation coefficients and making the necessary calculation, we have $-0.73, \pm 0.07$ as the correlation coefficient between the snowfall in March and the yield of wheat in Fulton County after eliminating the temperature influence.

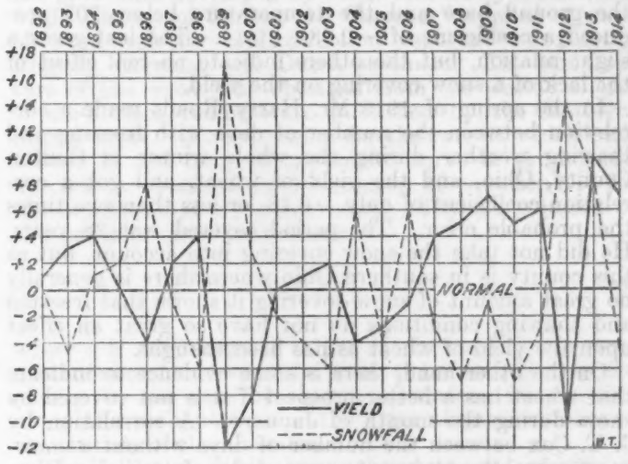


FIG. 1.—Curves showing the relation between the snowfall in March at Wauseon central Fulton County, Ohio, and the yield of wheat in that county. The solid line shows the variation of the yield from the average, in bushels per acre. The broken line indicates the departure of the snowfall from the average in degrees Fahrenheit.

The snowfall influence is eliminated from the temperature correlation in a similar manner by the equation:

$$(2) \qquad r_{ty.s} = \frac{r_{ty} - r_{st}\, r_{sy}}{\sqrt{(1-r_{st}^2)\,(1-r_{sy}^2)}}$$

Inserting the values and making the calculation we find the correlation coefficient between the March temperature and wheat yield reduced from $+0.62, \pm 0.09$, to the surprisingly low value of $+0.13, \pm 0.14$, after eliminating the effect of snowfall.

Dot charts, which are not reproduced here, substantiate the above and make plain the dominating influence of the March snowfall as compared with the March temperature. Unfortunately the available record covers only 23 years, but it is believed to be long enough to establish the fact that a heavy snowfall in March is detrimental to winter wheat in northern Ohio. This is substantiated by a chart prepared by Mr. Root for Illinois, but not reproduced in his article.

SNOW-COVERING AND WINTER-WHEAT.

A heavy fall of snow may melt quickly and leave the ground bare a good part of the month. On the other hand, a light total fall may remain on the ground over spells of unfavorable temperature conditions. Hence, the study of the effect of a covering of snow on wheat must be entirely separate from one on snowfall and wheat.

The general opinion is that winter grains should be covered by snow during cold weather and more especially when freezing and thawing conditions prevail. The results of studies in Ohio by the writer and by students taking the advanced course in Agricultural Meteorology at the Ohio State University show little to substantiate this opinion, at least during part of the winter.

A correlation between the number of days with snow on the ground from December to March, inclusive, and the yield of wheat in Fulton County, Ohio, gave a coefficient of only -0.14, ± 0.14. A correlation between the yield of wheat and the number of days in March with freezing weather, while the ground was bare, gave a coefficient of only -0.01. A correlation of the yield with the number of days during the whole winter with the ground bare and the temperature below 20° produced a coefficient of -0.28, ± 0.14. The last gives a slight relation, but the others indicate no real effect of the lack of a snow covering on the yield.

In the spring of 1915 Mr. Harry Roads made a correlation between the number of days with freezing and thawing weather during the whole winter in Clinton County, Ohio, and the yield of wheat, and got a correlation coefficient of only -0.18, or less than two times the probable error. The period covered was 28 years. He did not take the snow covering into account, but as this county is in southern Ohio where there is generally no great amount of snow-covering it shows that freezing and thawing conditions do not have so great an effect upon the yield of wheat as has been thought.

On the other hand, there is some evidence to indicate that wheat has a better prospect if it is not covered by snow during the month of January. A correlation by J. T. Cox between the number of days without a snow-cover when the temperature was below freezing in January and the yield of wheat in Wayne County, Ohio, gave a coefficient of $+0.49$, probable error ± 0.11. He found also that a large temperature range in January was beneficial.

Table 1 showed that a heavy snowfall in January was somewhat beneficial, while the above indicates that a snow-covering in that month may be detrimental. The explanation may be that a heavy snowfall in January melting quickly, as well as freezing and thawing weather while the ground is bare in this month, disintegrates the soil particles and settles the earth around the dormant roots and makes the plants better able to withstand later unfavorable conditions when they begin to develop.

Heaving is one of the most common causes of damage which usually occurs in the spring and is due to alternate freezing and thawing. It is possible, also, that a heavy snow-cover in January produces conditions favorable for smothering the grain, either from a very deep accumulation of snow, or, what is most common, the formation of an ice sheet from the partially melted snow.

The whole subject of winter damage to grains, whether by heaving, smothering, freezing of plants, or physiological drought, and the part that a snow-cover or lack of it, plays is worthy of a most thorough study. The facts given above, although based on too little data, may indicate the direction that the investigation should take.

PROTECTIVE POWER OF SNOW.

"The following observation [at Falling Royd, Hebden Bridge, Yorkshire, England] shows the remarkable extent to which a covering of snow protects the ground and plant life from intense cold. About 6 p. m. on the 13th of January a minimum thermometer was placed on the ground in the center of my lawn here, the temperature then being only a few degrees below freezing. Snow then fell to the depth of 1½ inches. At 11 p. m. the snow had ceased falling, and it was a bright starlight night and very cold. A second minimum thermometer was then placed on the top of the snow. No more snow fell in the night. In the morning the two thermometers recorded the following minimum temperatures: On the top of the snow, 2° F. below zero; under the snow, 24° F., or a difference of 26 degrees."

A. R. Crossley (in Symons's Meteorological Mag., Feb., 1918, 53:20).

TAYLOR'S THEORY OF ATMOSPHERIC TURBULENCE.

(Presented at a Physics Department Colloquium, University of Wisconsin.)

By ERIC R. MILLER, Meteorologist.

[Dated: Weather Bureau, Madison, Wis., Nov. 13, 1919.]

A theory of atmospheric turbulence, verified by numerous quantitative experiments, has been developed in three papers contributed to the Royal Society since 1914, by G. I. Taylor, Schuster reader in meteorology in the University of London in 1914, but since then an officer in the meteorological service of the British Army.

Taylor regards turbulence as made up of eddies and considers an eddy as air that moves from a stratum where it has the same temperature, humidity, and momentum as its surroundings to another stratum, with which it mixes. He makes no effort to separate kinetic and thermal turbulence. He does not, indeed, study individual eddies, although he makes use of such studies by Dines, but his work deals with the effects of turbulence in vertically transferring heat, humidity, and momentum. He neglects the effect of radiation in transferring heat from stratum to stratum, not only in dealing with observations at sea off Newfoundland, where cloudiness perhaps justified the assumption, but also in dealing with average conditions over Paris. His ideas and methods will perhaps be understood from the following summary of his papers:

In his first paper, "Eddy Motion in the Atmosphere," (*Philosophical Transactions*, volume 215, 1915, pages 1–26) Taylor arrives, from consideration of the transference of heat across a large horizontal surface at height z, at the expression

$$\frac{\partial \theta}{\partial t} = \frac{\overline{w}d}{2} \frac{\partial^2 \theta}{\partial z^2} \qquad (1)$$

for the propagation of heat by means of eddies, in which $\theta(z, t)$ is the average potential temperature of the air in the layer at height z at time t. w is defined by the relation $\frac{1}{2}\overline{w}d$ = average value of $w(z-z_0)$ over a horizontal plane, w being the vertical component of the velocity of the air, d the average height through which an eddy moves from a layer in which it was at the same temperature as its surroundings to the layer with which it mixes. $\frac{1}{2}\overline{w}d$ roughly represents the average vertical velocity of the air in places where it is moving upward. The divisor 2 is inserted because the air at any given point is equally likely to be in any portion of the path of an eddy, so that the average value of $z-z_0$ should be approximately equal to $\frac{1}{2}(d)$.

The similarity of equation (1) to the equation for the propagation of heat in a substance of conductivity κ, specific heat s and density ρ, viz:

$$\frac{\delta T}{\delta t} = \frac{\kappa}{\rho\sigma} \frac{\delta^2 T}{\delta z^2}$$

suggests that potential temperature is transmitted upward through the atmosphere by means of eddies in the same way that temperature is transmitted in a substance of conductivity κ. The atmosphere may be assumed, then, to have an eddy conductivity, provided $\frac{\kappa}{\rho\sigma} = \frac{\overline{w}d}{2}$.

The upward propagation of a bend (or inversion) in the temperature-height curve, due to the passage of air across the sharply defined boundary between the warm waters of the Gulf Stream, and the cold Labrador Current, over the Grand Banks of Newfoundland, is the first phenomenon employed by Taylor for the evaluation of the coefficient $\frac{1}{2}\overline{w}d$. The height of the bend was ascertained by Taylor by kite flights from the deck of the ice-scout steamer *Scotia* in the summer of 1913. The time required for the propagation of the bend to its observed altitude was determined by tracing the air back along its trajectory to the boundary between the warm and cold water. The trajectory was obtained by the procedure developed by Shaw and Lempfert in their "Life History of Surface Air Currents" applied to data of wind velocity and direction reported by passing English, German, and Dutch steamers. The temperature of the water was obtained from the weekly charts of sea-surface temperature published by the Meteorological Office. An expression for the rate at which such a bend in the temperature-height curve is propagated upward is obtained by integration of equation (1) for the conditions of the observation. Taylor's solution of this problem gives the relation

$$\frac{1}{2}\overline{w}d = \frac{z^2}{4t} \qquad (2)$$

where z is the observed height of the bend in the temperature-height curve, t the interval between the sudden change in the rate of change of surface temperature along the air's path, and the time of measurement of the altitude of the inversion.

The following table gives the data and results of seven determinations:

TABLE 1.

Date of observation.	z meters.	t hours.	$\frac{1}{2}\overline{w}d$ C. G. S. units.	Average wind force (Beaufort scale).
May 3, 1913	270	15	3.4×10^3	3.3
July 17, 1913	140	24	$.57 \times 10^3$	2.0
July 25, 1913	610	168	1.5×10^3	2.0-3.0
July 29, 1913	170	15	1.3×10^3	2.2
Aug. 2, 1913	200	11	2.5×10^3	3.0
Aug. 4, 1913 (two bends in temperature-height curve)	370	36	2.6×10^3	2.5
	770	120	3.4×10^3	3.1

It is to be expected that the turbulence will depend upon the wind velocity, hence it is not surprising to find that on July 17 and 29, when the wind force was about 2, the values of $\frac{1}{2}\overline{w}\,d$ are very much lower than on May 3, and August 2 and 4, when the wind force was about 3. The fact that the figures are so consistent, although t varies from 11 hours to 7 days, and z from 140 meters to 770 meters, indicates that the eddy motion does not diminish to any great extent in the first 770 meters above the surface.

The humidity-height curves obtained from the kite flights from the deck of the *Scotia* show bends at the same heights as the bends in the temperature curves, showing that changes in the amount of water vapor in the atmosphere are propagated upward in the same way as changes in temperature. This is to be expected, for it is evident that the reasoning which was used to deduce equation (1) would serve equally well to deduce an equation $\frac{\partial m}{\partial t} = \frac{\overline{w}d\partial^2 m}{2\partial z^2}$ for the propagation of water vapor into the atmosphere.

In dealing with the upward propagation of momentum by eddy motion it is necessary to take into account the horizontal components of eddy motion, because the eddy can gain or lose velocity owing to the existence of local variations in pressure over a horizontal plane. Such variations are known to exist; they are, in fact, a necessary factor in the production of disturbed motion. Taylor has been unable to solve the problem for motion in three dimensions, but for motions in the x, z, plane, limiting the analysis to incompressible fluids, he finds that, as before, in the case of the eddy conduction of heat, the average value of w' $(z-z_0)$ can be expressed in the form $\frac{1}{2}(\overline{w}d)$ where d is the average height through which an eddy moves before mixing with its surroundings, and $\overline{w}$ roughly represents the average vertical velocity in places where w' is positive. He finds that the effect of the disturbance in reducing the x-momentum is the same as that of a viscosity equal to $\rho\times$ average value of w' $(z-z_0)$, if the motion had not been disturbed. If the same relations hold for three-dimensional motion, then there is a relation $\frac{\kappa}{\rho\sigma}=\frac{\mu}{\rho}=\frac{1}{2}(\overline{w}d)$ between κ the eddy conductivity and μ the eddy viscosity.

Taylor next analyzes the effects of eddy viscosity in preventing the wind from attaining the velocity and direction expected on account of the pressure distribution. The most interesting results of this part of his work are the derivation of an expression for the ratio of the surface wind velocity to the gradient velocity differing essentially from that of Guldberg and Mohn:

$$Q_s/Q_G=\cos\alpha-\sin\alpha \quad \text{(Taylor)}$$
$$Q_s/Q_G=\cos\alpha \quad \text{(Guldberg and Mohn)}$$

and the analytical proof of the fact discovered empirically by Dobson, that the gradient direction is not attained until a height (800 meters) is reached that is more than twice the height (300 meters) at which the gradient velocity is first attained. Taylor's analysis also indicates that above the height at which the gradient direction is attained the wind goes on veering slightly up to a certain height, when it returns again to the gradient direction at a height slightly less than twice the height at which it first attained it. These results of theory are shown to agree closely with the results of observation by Dobson with pilot balloons at the Central Flying School at Upavon, on Salisbury Plain, and with observations by J. S. Dines, while the values of α calculated from Guldberg and Mohn's equation differ by 30° or more from the observed deflection of the surface wind from the gradient wind, and the gradient direction would be attained at the same level as the gradient velocity according to the theory of Guldberg and Mohn. By Taylor's theory the ratio of the height at which the wind direction first becomes the same as the gradient direction H_1 to the height H_2 at which the wind velocity first attains the gradient velocity varies with the deflection of the surface wind from the gradient wind, thus:

α	$\frac{H_1}{H_2}$
0 degrees	3.0
10 degrees	2.8
20 degrees	2.6
30 degrees	2.4
45 degrees	2.2

In Dobson's observations the value of $\frac{H_1}{H_2}$ averaged 2.66, and of α 20°, a remarkable coincidence of theory and observation, a coincidence that indicates that eddy motion does not diminish much in the first 900 meters, in the case of strong winds.

The author derives the following relation between H_1 and the eddy viscosity, for $\alpha=20°$

$$\frac{\mu}{\rho}=\frac{H_1^2\,\omega\sin\lambda}{(2.7)^2} \qquad (3)$$

where ω is the angular velocity of the earth 0.000073, and for the regions of observation in the south of England, and the Bank of Newfoundland $\sin\lambda=0.77$. Hence for these regions $\frac{\mu}{\rho}=H_1^2\times 0.77\times 10^{-5}$.

On land in the case of strong winds $H_1=900$ meters, hence $\frac{\mu}{\rho}=62\times 10^3$ in C. G. S. units.

For moderate winds $H_1=800$ meters, and $\frac{\mu}{\rho}=50\times 10^3$,

for light winds $H_1=600$ meters, and $\frac{\mu}{\rho}=28\times 10^3$.

At sea, assuming that the wind had reached the gradient velocity when it had practically stopped veering with increasing height, H_1 lay between 100 and 300 meters, so that $\frac{\mu}{\rho}$ lay between 0.77×10^3 and 6.9×10^3, values of the same order as those of the values of $\frac{\kappa}{\rho\sigma}$ in Table 1, tending to confirm the theoretical deduction that $\frac{\kappa}{\rho\sigma}=\frac{\mu}{\rho}$.

The author employs the relation $\frac{\mu}{\rho}=\frac{1}{2}\overline{w}\,d$ to determine from observations by J. S. Dines, the size of eddies. In the case taken the average wind velocity was 7 meters per second, the average deviation from the mean vertical velocity 25 cm. per second. d, which is rather less than the average diameter of an eddy, comes out as 40 meters. Since the wind velocity was 7 meters per second, or 420 meters per minute, it is evident that rather less than ten eddies would pass a given spot in a minute. Examination of Mr. Dines' record shows about six peaks per minute on the curve representing vertical velocity, showing that actual observations of eddy motion are in harmony with the assumptions on which the author's theory is based.

The paper closes with a note on the stability of laminar motion of an inviscid fluid. Interest in this question arises from the fundamental disagreement of the conclusion of Reynolds, that the more nearly inviscid the fluid the more unstable it is likely to be, with that of Rayleigh, that instability is impossible when the fluid is quite inviscid. Defining as unstable, motion in which the average value of the square of the distance of any portion of the fluid from the layer out of which the disturbance has removed it, increases with time, the author arrives at the conclusion that the discrepancy between Rayleigh's and Reynolds's work arises from the assumption of perfect slipping at the boundaries in Rayleigh's work, while the complete absence of slipping is assumed in Reynolds's work.

In his second paper, Taylor[1] invokes the aid of the principle of dynamic similarity in testing his theory. In this case it is considered that the tangential force exerted by the wind as it blows over a large tract of land is equal to the skin friction on a similar small surface when subjected to the action of the very high wind which would correspond to the same value of lV/ν (where l represents the linear dimension of the system, V the velocity of the fluid, and ν the kinematic velocity).

[1] *Taylor, G. I.* "Skin friction of the Wind on the Earth's Surface." Proc. Roy. Soc., Ser. A, vol. 92, pp. 196–199.

The trees and houses on the tract of land reduce to the mere roughness on the plate.

For the purpose of comparison the skin friction of the wind is expressed in the form

$$F=\kappa\rho Q_s^2 \qquad (4)$$

Q_s being the wind velocity near the surface, ρ the density of the air, and κ the constant of skin friction.

The highest values of lV/ν obtained by Stanton at the National Physical Laboratory, working with a fluid flowing through a pipe, are expressed by the formula $F=0.004\,\rho V^2$ where V is the velocity of the fluid near the wall, ρ is the density of the fluid, and .004 is the value of the constant κ.

From the equations in his paper on Eddy Motion, Taylor obtains the following expression for κ in the atmosphere

$$\kappa=\frac{2\mu}{\rho}\sin\alpha\frac{\frac{3}{4}\pi+\alpha}{H_1}\frac{Q_g}{Q_s}$$

where the symbols have the same meaning as before. Substituting in this equation the data obtained by Dobson the following values of κ are found:

	$\frac{\mu}{\rho}$	α	H_1	Q_g	Q_s	κ
			Meters.	*cm/sec.*	*cm/sec.*	
Light winds	28×10^3	13°	600	460	330	0.0023
Moderate winds	50×10^3	21½°	800	910	590	0.0032
Strong winds	62×10^3	20⅔°	900	1,560	950	0.0022

It is concluded (1) that κ does not appear to increase or decrease with wind velocity, a threefold increase in velocity corresponding to a ninefold increase in skin friction. It appears therefore that the skin friction on the earth's surface is proportional to the square of the wind velocity: (2) Since the values of the skin friction coefficient in the atmosphere, 0.002 to 0.003, are of the same order, but slightly smaller than the values found in the laboratory, 0.004, although the scale of the two phenomena differs in the ratio 100,000 to 1, it is evident that the same law of skin friction applies to the friction of the atmosphere on the ground as to small flat plates and pipes. The ratio of the velocity of the fluid near the wall in a pipe to the velocity in the middle, 0.6, is comparable to the ratio of wind velocity near the ground to the gradient wind, which is 0.7 for light winds, 0.6 for strong winds.

A third paper by Taylor deals with the evidence afforded by the daily variation of temperature at various heights on the Eiffel Tower as to the transference of heat by turbulence, and with the relation of turbulence to the daily variation in wind velocity at various heights.

In this paper the power possessed by the atmosphere in virtue of its turbulence of transmitting heat and momentum is represented by the symbol K, which is stated to be roughly equal to the expression $\frac{1}{2}\overline{v}d$ that appeared in the first paper.

The temperature observations on the Eiffel Tower were made during the five years 1890–1894, at altitudes of 123, 197, and 302 meters above ground. Observations at 18 meters are also available from the station on the terrace of the Bureau Météorologique. For the purpose of simplifying the computation the curves of diurnal march of temperature are replaced by the true sine curves which most nearly represent the real curves. Solution of the equation for the convection of heat by turbulence gives the relation

$$K=\frac{\pi}{T}\left(\frac{h}{\log_e R_1-\log_e R_2}\right)^2$$

where R_1 and R_2 are the ranges at two heights z_1 and z_2, which differ by an amount h, while T is the period of daily variation, 24 hours or 86,400 seconds.

The mean values of K between various heights are shown in the following table:

Month.	1 18 to 302 meters.	2 123 to 322 meters.	3 197 to 302 meters.	4 18 to 123 meters.
January	4.3×10^4	2.9×10^4	2.7×10^4	11×10^4
February	6.4	4.1	1.6	20
March	10.5	8.3	7.7	24
April	10.2	10.5	8.2	14
May	12.9	14.4	16.7	11
June	18.3	24.4	28.8	12
July	16.7	23.4	30.1	13
August	14.6	13.1	19.6	18
September	8.0	7.2	7.5	10
October	5.9	4.9	5.3	9
November	5.4	3.2	2.5	18
December	6.5	4.4	2.8	15
Mean	10.0×10^4			

It will be seen from the table that the turbulence appears to decrease with height in winter, and to increase in summer. This is explained by reference to the vertical temperature gradient of the two seasons. The mean temperature gradient up to 300 meters is considerably less than the adiabatic gradient in winter, and the number of occasions when the adiabatic gradient is comparatively small. Such a gradient, less than the adiabatic, has a tendency to prevent the spontaneous formation of turbulence, and to suppress it when formed by outside agencies, such as obstacles on the ground. In summer the mean temperature gradient in the first 300 meters is much more nearly adiabatic, and the number of occasions when it reaches the adiabatic gradient is large. A gradient equal to the adiabatic has a tendency to encourage the spontaneous formation of turbulence. An increase in the value of K with height in summer is therefore to be expected because K is roughly proportional to the eddy component of turbulent velocity and to the diameters of the eddies.

The values of K near the ground are shown in column 4. These values are less accurate because the method used in deducing K is most liable to error in this case, where the temperature variations are large, and they consequently vary in an apparently haphazard way, yet they show no indication of the annual march so clearly exhibited in all the other columns. The temperature gradient is thought therefore to have little effect on the turbulence in this stratum, which is governed more by the nature of the ground, and by the wind velocity which shows no marked annual march at Paris.

The change in wind direction between the top and bottom of the Eiffel Tower has already been used by Dr. F. Åkerblom to find the viscosity of the atmosphere due to turbulence. This quantity, which is of course equal to K/ρ was found to be about 85 C. G. S. units in winter, and 115 in summer, a difference in the same sense, but considerably less in amount than that indicated by column 1 in the foregoing table. The mean value of K/ρ is given by Dr. Åkerblom as 95 C. G. S. units. Taking the density of the air, ρ, as 0.00125, the value of K from wind velocity measurements comes out

7.6×10^4, which is comparable with the value of 5×10^4 found by Taylor from wind velocity measurements over Salisbury Plain, where the turbulence would be expected from the nature of the ground to be less than over Paris. The agreement between these values and the value of 10×10^4 from the temperatures observed on Eiffel Tower is quite as good as could be expected, considering the approximations in the calculations, and affords satisfactory confirmation of the theory that momentum and heat are transmitted by the same agency, and that the behavior of the lower atmosphere in transmitting heat can be calculated from observations of the retardation of the lower layers of the earth's atmosphere by the friction of the ground.

The remainder of the paper is devoted to the interpretation of the low-level reversal in the type of diurnal march of wind velocity recently brought to light by Hellmann's observations.[2]

The complementary types of diurnal march of wind velocity (1) with a maximum in the middle of the day, observed near the ground, and (2) with a minimum in the middle of the day, on mountains, are well known. Hellmann's observations with anemometers at 2, 16, and 32 meters above the ground show the upper-air type approaching near enough to the ground when the wind is light to give maxima in the middle of the night at 16 and 32 meters. At 16 meters the maxima of midday and midnight are about equal, at 32 meters the night maximum is greater than the day maximum. In strong wind the march is characterized by a midday maximum, and midnight minimum at all of the anemometers.

The Espy-Köppen theory according to which both types of daily variation are the results of midday convectional ascending currents, the circulation of which carry the more stagnant air up from the ground to reduce the velocity of the higher layers, and the faster-moving upper wind down to the ground to increase the velocity of the surface wind, fails to account for Hellmann's observations, because it leads to the conclusion that the vertical currents due to the heating of the ground must extend to a much greater height in strong winds than they do in light winds.

The theory of turbulence, involving frictional as well as convectional interchange of air at different levels affords a satisfactory quantitative explanation of the phenomena observed by Hellmann. In the absence of determinations of the diurnal variation of K, it is necessary to estimate what this would be from the annual variation of K shown by the Eiffel Tower observations. K is assumed to vary continuously from a maximum at midday to a minimum at midnight, in such a way that the corresponding values of the angle α between the directions of the surface wind and the gradient wind vary through the entirely probable range from 10° at midday to 30° at midnight. The velocities are then taken off a graphic representation of the vertical distribution of wind velocity corresponding to a series of values of α. Curves[3] obtained in this way for a series of arbitrary heights agree exceedingly well with the march actually observed by Dr. Hellmann.

The data obtained in various ways as to the value of K are used to estimate the limits to which the ground type of daily march of wind velocity is likely to extend, the results being given in the following table:

		Gradient velocity m. p. s.	At midday.		At midnight.		Height at which maxima at midday and midnight are equal.
			K	α	K	α	
							Meters.
Strong winds	Summer	13.6	40×10^4	12	6×10^3	28	60
	Winter		13×10^4	17			50
Light winds	Summer	4.6	20×10^4	7	1×10^3	26	30
	Winter		7×10^4	10			25

These theoretical conclusions agree with Dr. Hellmann's observations, in which the reversal in light winds occurred at about 16 meters in winter and about 32 meters in summer. The reversal in strong winds was above all three anemometers, and also above the anemometer 41 meters above the ground at the meteorological observatory at Potsdam.

Taylor's coefficient of eddy conductivity appears to be an important meteorological constant. Its applicability in the dynamics of the lower atmosphere is obvious. That it may be of great practical importance is indicated by the successful elucidation of Hellmann's observations, which are evidently closely related to the phenomenon of the nocturnal inversion of temperature. Observations of it may become essential to the successful forecasting of agricultural frosts.

[2] Uber die Bewegung der Luft in den untersten Schichten der Atmosphäre. Met Zeit, Jan. 1915, vol. 32, pp. 1–16.

[3] Given in the original paper, but not reproduced here.

ATMOSPHERIC STIRRING MEASURED BY PRECIPITATION.

By LEWIS F. RICHARDSON.[1]

[Abstracted from Proceedings of the Royal Society, Series A, vol. 96, No. 674, pp. 9–18, 1919.]

Gentle mixing of a definite portion of air does not alter the total amount of water in it; any increase in the amount must come from water flowing in over the sides of that portion of air. Taking a large horizontal layer of air, and defining *upward flux* as the ratio of amount of water rising across a large horizontal surface in unit time to the area of the surface, we can *define* a coefficient c, such that

$$\varphi = -c\frac{\partial x}{\partial h},$$

where φ is upward flux, h is height, x is amount of water per unit mass of air. When a definite portion of air is removed from one level to another, the total amount of water associated with it does not, of course, change, and hence x does not change, and φ is zero when $\partial x/\partial h$ is zero. It is then very easy to show that

$$\frac{\partial x}{\partial t} = \frac{\partial}{\partial p}\left(\xi\frac{\partial x}{\partial p}\right)$$

is the equation for diffusion, where p is pressure, and ξ is equal to $g^2\rho c$, ρ being density; also that

$$\varphi = -\frac{\xi}{g^2\rho}\frac{\partial x}{\partial h},$$

ξ being the stirring coefficient, or measure of degree of atmospheric turbulence. Since on the average the water-content of the atmosphere is not increasing, the water which descends as precipitation must have been stirred

[1] Cf. Science Abstracts, Nov. 29, 1919, pp. 502–503.

up into the atmosphere. φ gives the mass of water in the form of vapor rising across one horizontal square centimeter per second *on the average of a large horizontal area*, and this must then be equal to the average rate of rainfall at that level. We extend the area to cover the entire globe; then taking the layer of the atmosphere in the kilometer next above the ground, and inserting in the equations the mean values of the vertical gradient of mass of water per mass of air, and the mean values of the density and rate of precipitation, we find ξ at 500 meters to be 140,000 cm.$^{-2}$ grm.^{2} sec.$^{-6}$; similarly, taking the layer in which the upper clouds occur, at which height the precipitation consists only of the slow descent of the clouds themselves, and estimating the amount and size of the cloud-particles (*cf.* L. F. Richardson, *Proc. Roy. Soc.*, A96, 19–31, 1919), it is possible to get ξ at 8.5 kilometers to be from 3 to 180 C. G. S. For the layer in the meter next above the ground, some psychrometric observations indicate that ξ for 0.5 meter is 1,000 or less.

The value at 500 meters is in fair agreement with the value deduced from certain experimental investigations.

In the stratosphere, ξ must, of course, be so small that the equality of temperatures will not be disturbed.

The mean values being taken over the whole globe, the effects of the largest circulatory motions between the poles and the equator are combined with those of rising currents in cyclones, anticyclones, cumulus eddies, etc., in deducing the value of the coefficient of eddy-diffusivity, the latter thus becoming a statistical measure of the effects of circulatory motions which we can not or do not wish to consider in detail.

The quantity x may also be entropy, potential temperature, or velocity in a fixed azimuth, all per unit mass, and hence the equations have applications to the mechanics of eddy motion in the atmosphere.

These equations are an improvement on similar ones derived by Taylor, the effect of altitude being considered (*Phil. Trans.*, A215, p. 3, 1915).—*E. W. W[oolard]*.

A FORMULA FOR THE RELATION OF MEAN WIND VELOCITY TO ALTITUDE WITH RESPECT TO HELLMANN'S INVESTIGATIONS.[1]

By DR. F. BRADTKE.

[Abstracted from *Meteorologische Zeitschrift*, Nov.-Dec., 1918, vol. 35, pp. 313–315.]

In Hellmann's work on "The Motion of Air in the Lower Layers of the Atmosphere," he deduces two formulae to be applied in obtaining the mean wind speed at various elevations, the one for extremely low elevations, the other for the higher. These are:

$$(1)\quad v = a + b \log (h + c), \text{ and,}$$

$$(2)\quad v/v_0 = \sqrt[5]{h/h_0},$$

the first to apply above 123 meters, the second below 16 meters. He implies that there can be no simple expression for use at all altitudes.

The following equation has been determined, which, as will be shown, gives, with great accuracy, the speed at any elevation:

$$v = 1.2 + 1.79\, h^{0.248}$$

[1] Meteorol. Zeitschr., 1917, vol. 34, p. 273.

To show the accuracy with which this formula can be used the following table gives the mean wind velocity as determined at various heights by Hellmann at Nauen; and below them are presented the values as computed by this formula:

h=	2	16	32	123	258	meters
v= observed	3.33	4.69	5.40	7.02	8.26	m. p. s.
v= computed	3.32	4.74	5.40	7.05	8.22	m. p. s.

Carrying the test farther, the computed value for 305 meters is 8.51 meters per second, and the observed value on the Eiffel Tower is 8.71 meters per second; the computed speed is 9.32 meters per second for 500 meters and the observed value from Lindenberg kite flights for this elevation is 9.3 meters per second. Hellmann's formula gives 8.48 and 9.25 meters per second, respectively.—*C. L. M.*

ON THE DEPENDENCE OF WIND SPEED UPON ALTITUDE.

By V. LASKA.

[Abstracted from *Meteorologische Zeitschrift*, Nov.-Dec., 1918, vol. 35, pp. 315–316.]

The calculations are based upon an interpolation formula in which h is altitude above the ground in meters, and v the wind speed in meters per second, as follows:

$$\log v_x = \log v_1 [1 + (x-1)/10] \qquad (1)$$

in which

$$h = 2^x,\ h < 500 \text{ meters.}$$

The comparison of calculated to observed values in the vicinity of the ground is given in the following table:

TABLE 1.

h	2	4	8	16	32	64	128	256	512
v Calculated	3.4	3.9	4.4	4.9	5.6	6.3	7.1	8.0	9.1
v Observed	3.3	—	—	4.7	5.4	—	7.0 (h= 123)	8.3 (h= 258)	9.1

When $h = 0$, Hellmann has given a value of wind speed of 2.8, but the author takes the stand that the formula gives the correct value of 0.0; in other words, in order to account for the wave-forming tendency of the air, there must be a quiet layer—perhaps only a few millimeters in thickness, next to the ground. It follows that there is a very sudden increase in the immediate vicinity of the ground. The original formula is simplified to—

$$\log v / \log h = c \qquad (2)$$

Where there are several elevations we have

$$\log v_1 v_2 \ldots v_n / \log h_1 h_2 \ldots h_n = c \qquad (3)$$

The demonstration of this is shown in Table 2.

TABLE 2.

	Jersey.	Zikawei.		Nauen.		Strassburg.			Chicago.		
h	55	12	41	16	32	18	52	144	32	47	83
v_n	7.4	3.6	5.9	4.7	5.4	2.8	4.2	6.0	4.2	4.6	7.8
c	.050	0.52	0.48	0.56	0.49	0.36	0.36	0.36	0.41	0.40	0.46
c (formula 3)	.050		0.49		0.52		0.36			0.43	

It appears that the relation $v=\sqrt{h}$ and also the formula of Hellmann, $v/v_1=\sqrt[3]{h/h_1}$ yield similar results. We can write this last equation as

$$\frac{\log v-\log v_1}{\log h-\log h_1}=c$$

which can be rewritten as

$$\log v-c\log h=\log v_1-c\log h_1=C.$$

If C approaches zero we obtain formula 2. These formulae can only be used as interpolation formulae and are limited to the reduction of observations of wind.—*C. L. M.*

DAILY MARCH OF WIND VELOCITY AT 30 M. ABOVE OSTEND AND 90 M. ABOVE BRUGGE.

By ALBERT PEPPLER.

[Abstracted from *Meteorologische Zeitschrift*, March–April, 1919, vol. 36, pp. 90–93.]

During the war measurements of wind velocity were made both at Ostend and at Brugge. The Ostend curve is a relatively simple one, showing a minimum at 3 a. m., a steady increase in speed to 3 p. m., and a quite steady fall again to the minimum. This period is especially marked on hot summer days. The Brugge curve is more complex. The principal minimum occurs at about 8 a. m., after which there is a steady increase to 1 p. m., followed by a fall to a secondary minimum at 8 p. m., and then a rise to the secondary maximum at 1 a. m. Thus, there are two 12-hour periods which combine to give wide variations in the daytime and secondary variations at night. It should also be noted that the higher anemometer gives speeds of smaller magnitude during the day and of greater magnitude during the night than the lower one.—*C. L. M.*

THE DIURNAL VARIATION OF WIND VELOCITY IN THE FREE AIR.

By J. ROUCH.

[Abstracted from Comptes Rendus, Paris Acad. Aug. 11, 1919, pp. 293–295.]

In the upper layers of the atmosphere, different diurnal variations of wind velocity are observed from those in the lower layers. The speed is a maximum during the night and a minimum during the day. This has been observed by Angot on the Eiffel Tower and is substantiated by numerous mountain stations.

Certain pilot balloon observations made during the summer of 1918 have been grouped by time of day and the mean differences between the two times taken for a given level. These were grouped for morning and afternoon. In Table 1 the plus sign (+) denotes an afternoon wind greater than a morning wind; the minus sign (−) indicates an afternoon wind less than the morning wind.

This table shows that the wind speed in the morning is greater than the afternoon wind at 200 meters at Bayonne, Cette, and Rochefort; between 200 and 400 meters at Havre; between 400 and 600 meters at Oran; and, as has been mentioned, at Paris, at an altitude of 300 meters, it is a maximum during the night and a minimum during the day. This difference is noted to an altitude of 2,000 meters, although it is a maximum at about 1,000 meters. Above 2,000 meters it appears that the time of day does not make much difference, although there is a slight indication that the winds of afternoon above that level are greater than those of the morning. Above the 3,000-meter level observations are insufficient for drawing conclusions; below, it is believed that the above-stated relations are valid.—*C. L. M.*

TABLE I.

Stations.	Times.	Altitudes (meters).											
		0	200	400	600	800	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Oran (58)[1]	7 a. m.–4 p. m.	+4.7	+2.7	+0.4	−0.9	−1.7	−1.4	−0.4	−0.2	+0.4	+1.8	.....	.....
Bayonne (44)	7 a. m.–1 p. m.	+3.7	−0.4	−2.3	−2.1	−0.9	−0.4	−0.3	−1.1	−0.9	−0.1	.....	.....
Cette (69)	7 a. m.–1 p. m.	+1.2	−0.8	−2.2	−1.6	−1.5	−1.7	−1.3	.....	.....	.....	.....	.....
LeHavre (21)	7 a. m.–1 p. m.	+2.5	+0.5	−1.8	−2.0	−1.5	−1.0	−1.2	.....	.....	.....	.....	.....
Rochefort (36)	7 a. m.–12 m.	+1.5	−4.6	−3.6	−3.2	−2.1	−0.8	−0.7	−0.8	−0.2	0.0	.....	.....
Saint-Cyr (40)	7 a. m.–2 p. m.	+1.7	.....	.....	.....	.....	−0.8	.....	+0.6	.....	+0.5	.....	+0.3

[1] Numbers in parentheses indicate number of observations.

THE INFLUENCE OF THE VELOCITY OF THE WIND ON THE VERTICAL DISTRIBUTION AND THE VARIATIONS OF THE METEOROLOGICAL ELEMENTS IN THE LOWER LAYERS OF THE ATMOSPHERE.

By C. E. BRAZIER.

[Comptes Rendus, Paris Acad. Sci. January 20, 1919, pp. 179–182.]

The barometric pressure at the ground level, calculated from observations made on the Eiffel Tower, is lower than the observed pressure. When the mean wind for 24 hours is 0.9 meters per second on the ground, and 4.4 meters per second at the top of the tower, and the surface pressure was 761.4 mm. and the tower pressure was 736.5 mm., the computed ground pressure was 761.3 mm., thus showing a difference of 0.1 mm. In the case of a moderate wind (mean velocity, base 2.1, top 8.1 m/s) this difference is 0.2 mm., and in the case of a strong wind (mean velocity, base 3.7, top 11.5 m/s) it increases to 0.3 mm., showing clearly that the difference increases with the speed of the wind.

The discussion is closed with the following three conclusions relative to other meteorological relations: "1st. For a given diurnal variation of the amount of heat received by the earth from the sun, the amount of the diurnal variation of air temperature in the immediate neighborhood of the ground, is greater for a gentle wind than for a strong one.

"2d. Except at a certain level, the altitude of which may vary with the season and the place of observation and which, in April and above Paris, is lower than 200

meters, the amplitude of the daily variation of air temperature increases, other things being equal, with the speed of the wind.

"3d. It appears, therefore, that in our situation, it is possible to conclude that there is a certain layer of air situated at a relatively low altitude above the earth in which the diurnal variation of temperature is independent of the speed of the wind."—*C. L. M.*

THE INFLUENCE OF THE VERTICAL DISTRIBUTION OF TEMPERATURES ON THE VELOCITY OF THE WIND NEAR THE SURFACE.

By C. E. BRAZIER.

[Abstracted from Comptes Rendus, Paris Acad., June 10, 1919, pp. 1160-1161.]

Having previously shown that the speed of the wind influences the vertical distribution and diurnal variation of the meteorological elements in the lower layers of the atmosphere (see abstract above), the author now finds that a comparative study of the gradient and of the speed of the wind near the surface (over the continents) demonstrates that the diurnal variation in the speed of the wind can not be explained by any diurnal change of the gradient, but only by an exchange between the surface and higher layers, the intensity and extent of which would depend upon the vertical temperature distribution. Utilizing observations at the Central Office (elevation 21 meters) and the Eiffel Tower (elevation 305 meters), and obtaining the gradients from the daily maps, he investigates the effect of vertical temperature changes upon the winds given by the gradients. Preliminary results indicate that at the Central Office whatever the direction and value of the gradient, the measured wind speed is on the average, less, for that given gradient, when there is an inversion of temperature, than when the contrary is true; the speed increases progressively as the decrease of temperature upward becomes more marked in the lower 300 meters. At the summit of the Tower, however, the speed, for a given gradient, becomes a maximum when the temperature at that level approaches the simultaneously existing temperature at the Central Office. These results are not due to the greater frequence of inversions during light winds.

The results indicate that the ratio of wind velocity to gradient at the height at which anemometers are placed is too greatly influenced by the vertical temperature distribution for the latter to be neglected in the experimental determination of the law connecting the two quantities.—*E. W. W.*

ON THE RELATION OF WIND TO THE GRADIENT IN THE LOWER LAYERS OF THE ATMOSPHERE.

By C. E. BRAZIER.

[Abstracted from Comptes Rendus, Paris Acad., Oct. 27, 1919, pp. 730-733.]

In the paper abstracted just above the author showed that the speed of the wind in the lower layers of the atmosphere was not only dependent upon the gradient, but also upon the vertical distribution of temperature. In this paper he discusses the angle made by the wind direction and the gradient, which is dependent upon the pressure distribution and also upon the vertical distribution of temperature. First, with a constant pressure gradient, he finds that the angle between the wind and the gradient at the surface is less when there is an inversion of temperature. With the temperature gradient constant, and the pressure gradient increased, the wind at the surface blows more nearly along the isobars. At the top of Eiffel Tower, with a constant pressure gradient, the effect of the inversion is much less marked, and what change there is appears to be in the opposite direction, i. e., toward parallelism with the isobars. In treating the angle between the wind at the top of the tower and that at the surface, use is made of the study of Angot, who found a diurnal variation in this difference; and this diurnal variation can be considered the result of the variations in the vertical distribution of temperature. The study of the concomitant variations of the temperature and of the speed of the wind in the first 300 meters leads to a conclusion that the total variation in the vertical distribution of temperature near the ground affects a layer of air relatively thin, but that its effect is felt to an elevation greater than that at which the gradient wind is usually found.—*C. L. M.*

HUMIDITY AND VAPOR PRESSURE AT TAMPA, FLA.[1]

By WALTER J. BENNETT, Meteorologist.

[Dated: Weather Bureau, Tampa, Fla., July 29, 1919.]

The following table gives the bi-hourly averages of relative humidity, temperature, vapor pressure, and vapor pressure ratios (to mean of 7 a. m. and 7 p. m.), for each month at Tampa, Fla., for the period August, 1915, to December, 1918. It is thought that this table is valuable as an addition to data published in MONTHLY WEATHER REVIEW, SUPPLEMENT 6, 1918. It gives the only data for a southern station. The remarkable feature is the occurrence of the minimum vapor pressure in the middle of the day (except January and December).

TABLE 1.—*The mean bi-hourly (ninetieth meridian time) relative humidity, air temperature (°F.) vapor pressure (inches), and "vapor pressure ratio" at Tampa, Fla., for the period August, 1915, to December, 1918, inclusive.*

	A. M.						P. M.					
	2	4	6	8	10	Noon.	2	4	6	8	10	Mid't.
January:												
Relative humidity	86	87	87	82	68	59	56	60	71	77	81	84
Vapor pressure	.420	.412	.408	.434	.430	.419	.418	.426	.444	.445	.421	.435
Temperature	57	56	56	58	64	68	70	68	64	62	60	58
Vapor pressure ratio	.981	.963	.953	1.014	1.005	.979	.977	.995	1.037	1.040	.984	1.016
February:												
Relative humidity	81	81	82	75	60	51	47	51	64	73	77	80
Vapor pressure	.409	.398	.396	.415	.405	.388	.374	.386	.415	.426	.425	.419
Temperature	58	56	56	60	65	69	71	69	65	62	60	59
Vapor pressure ratio	.998	.971	.966	1.012	.988	.946	.912	.941	1.012	1.039	1.037	1.022
March:												
Relative humidity	79	80	80	69	53	46	44	49	60	70	75	77
Vapor pressure	.430	.424	.418	.439	.398	.378	.376	.388	.418	.445	.450	.430
Temperature	60	59	58	64	69	72	73	72	67	64	63	61
Vapor pressure ratio	1.031	1.026	1.002	1.053	.955	.906	.902	.930	1.002	1.062	1.079	1.031
April:												
Relative humidity	81	83	83	67	52	46	44	49	59	70	75	78
Vapor pressure	.482	.480	.492	.498	.453	.430	.424	.443	.473	.498	.504	.500
Temperature	63	62	63	70	74	77	79	77	72	69	67	65
Vapor pressure ratio	.980	.976	1.000	1.012	.921	.874	.862	.900	.961	1.012	1.024	1.016
May:												
Relative humidity	84	86	86	68	54	48	48	52	60	70	76	81
Vapor pressure	.637	.625	.650	.632	.573	.547	.548	.564	.589	.618	.630	.638
Temperature	70	69	71	76	81	83	84	82	79	75	73	72
Vapor pressure ratio	1.016	.997	1.037	1.008	.913	.872	.874	.900	.936	.985	1.005	1.018
June:												
Relative humidity	84	86	85	70	57	53	52	58	66	75	79	82
Vapor pressure	.724	.720	.756	.723	.694	.653	.626	.671	.707	.732	.738	.732
Temperature	75	74	76	81	84	86	86	85	82	79	77	76
Vapor pressure ratio	.995	.989	1.038	.993	.953	.897	.860	.922	.971	1.005	1.014	1.005
July:												
Relative humidity	87	88	86	71	61	56	57	62	70	78	82	85
Vapor pressure	.780	.772	.808	.786	.728	.697	.723	.730	.759	.780	.795	.792
Temperature	76	76	77	82	85	87	86	85	82	80	78	77
Vapor pressure ratio	.998	.987	1.033	1.005	.930	.897	.924	.934	.971	.998	1.017	1.013
August:												
Relative humidity	88	89	88	73	61	56	57	64	73	80	84	86
Vapor pressure	.782	.773	.807	.803	.753	.723	.717	.741	.764	.787	.799	.792
Temperature	76	75	77	82	86	88	88	85	81	79	78	76
Vapor pressure ratio	.987	.976	1.019	1.014	.951	.913	.903	.935	.965	.994	1.009	1.000
September:												
Relative humidity	88	89	89	77	63	56	56	61	71	79	83	86
Vapor pressure	.730	.720	.733	.762	.705	.674	.674	.679	.712	.727	.730	.736
Temperature	74	73	74	79	83	85	86	84	80	77	76	75
Vapor pressure ratio	.993	.978	.997	1.037	.959	.914	.914	.924	.969	.989	.993	1.001
October:												
Relative humidity	82	87	88	76	62	56	55	59	71	78	83	84
Vapor pressure	.632	.624	.628	.656	.626	.603	.591	.599	.637	.649	.650	.635
Temperature	69	69	69	74	79	81	82	80	76	73	72	70
Vapor pressure ratio	.978	.964	.972	1.014	.971	.935	.917	.929	.972	1.003	1.005	.985
November:												
Relative humidity	80	82	82	70	57	49	48	52	64	72	76	80
Vapor pressure	.444	.435	.430	.446	.435	.418	.411	.430	.461	.476	.476	.475
Temperature	61	60	59	64	70	74	74	72	68	65	63	62
Vapor pressure ratio	.993	.973	.962	.998	.973	.913	.919	.962	1.031	1.065	1.065	1.062
December:												
Relative humidity	83	84	86	79	67	58	55	59	69	75	79	82
Vapor pressure	.38$_8$	.381	.374	.390	.400	.399	.392	.399	.404	.413	.415	.393
Temperature	5$^2_5$	54	54	57	63	67	68	66	62	60	58	56
Vapor pressure ratio	.98$^5_5$	.967	.949	.989	1.016	1.010	.995	1.010	1.025	1.053	1.016	.997

[1] The table was submitted as Table 4 in the author's contribution, "Diurnal variations in humidity," published in the Monthly Weather Review, July 1919. 47: 466-468; but it was unfortunately omitted.—ED.

THE RELATIONSHIP BETWEEN CIRRUS MOVEMENTS FROM EASTERLY POINTS, AND THE OCCURRENCE OF SEVERE DROUTHS.

By GEORGE REEDER, Meteorologist.

[Dated: Weather Bureau, Columbia, Mo., Oct. 29, 1919.]

SYNOPSIS.

During severe drouths in summer, and preceding them, the cirriform clouds show a persistent though very sluggish movement from easterly points. This drift rarely is interrupted by the local thundershowers that occasionally occur, but ceases just before, or coincidently with, the general rains that break the drouth. During the period of drouth and cirriform cloud movements from easterly points, the cirri generally are few in amount and thin in structure; and they seem to evaporate and disappear quickly.

The phenomenon appears to be associated with a certain type of high pressure, known as the Hudson Bay anticyclone, which moves southerly in series, and, after the apex is over the Lake region or Ohio Valley covers the eastern half of the United States. These anticyclones appear to be of exceptionally great vertical extent.

INTRODUCTION.

The more or less severe summer drouth that periodically visits our middle western agricultural States, and which, in fact, has been quite a frequent visitor to Missouri during the present decade, is one of the most interesting and important phenomenon of our western North American climatology. A satisfactory explanation as to the cause or causes would, of course, possess great economic significance. As is quite obvious the cause or causes are not wholly local, the solution of the physical process that precede and are associated with severe drouths must probably await the application of world-wide meteorology and, perhaps, a larger understanding of the relationships existing between the troposphere and stratosphere. It seems to be a subject worthy of the best efforts of our advanced students of meteorology.

The scientific study of the upper-air currents, however, is not possible to the average observer, because of the lack of proper instruments for determining quantitative values of the several factors involved. In presenting this paper, which deals with upper-air studies, no attempt will be made to treat the subject exhaustively, because, though it embodies many careful eye observations, the data of all quantitative values are lacking. For instance, eye observations of the structure of the clouds give us but a vague idea of the temperature of the current in which they float and no certain value as to height or rate of movement, but, on the other hand, the careful observer can determine their direction of movement with considerable exactness.

During the severe drouth of the summer of 1911, in Missouri, I was impressed by a persistent though extremely slow movement of thin cirriform clouds from the northeast, east, and southeast, and points between. With such movements from abnormal directions, heretofore considered, beginning before and persisting generally throughout the period of drouth, a keen interest was aroused that caused a very careful scrutiny of all cirriform clouds through the succeeding years. On the whole, severe and widespread drouths are not common in Missouri, and, except the remarkable series of the present decade, do not occur more than once in 10 years. So well was this understood that it was a common saying, prior to 1911, especially among the agricultural class, that two successive summer severe drouths were an unheard-of occurrence in Missouri. Closely following the drouth of 1911 came the drouths of 1913 and 1914, and following the wet and cool summer of 1915, came the drouths of 1916, 1917, and 1918. Rather a serious application from the standpoint of the agriculturist, but a rare opportunity for the meteorologist for the compilation of cloud statistics during drouths has been afforded, and with the recurrence of the abnormal drift of cirrus clouds from easterly points with each drouth, there seems to be some definite connection between these two abnormal conditions.

It might be said at the outset that the entries of cirri in our station records of past years do not well substantiate the conclusions of this paper, and it is not likely that those of other stations will do so. In the first place, the cirriform clouds of drouth times generally are thin and a few in amount, and might be omitted altogether by the casual observer. At such times as they are present in sufficient amount to attract notice their rate of movement is so sluggish, especially when moving from some easterly point, that the 20-minute period usually given to an observation is much too limited, and hence there is a strong tendency on the part of the observer to enter no direction or to assume them from some westerly point, since that is considered their normal direction. Whenever cirri are observed to be moving unusually slowly it is very probable that they are from some direction other than westerly, though it is true they do occasionally move exceedingly slowly from western points during periods of drouth. It is doubted whether cirri ever remain absolutely stationary, though at times the lack of structure prevents the observer from determining their direction to a certainty. Frequent and careful observations ought to be made of cirriform clouds all the year round, but particularly so in spring and summer, and entries verified whenever possible by the official in charge or a competent assistant to the end that what follows may be, if the relations of cause and effect can be traced, put to actual practice as soon as possible, because, as already mentioned, the possibilities of forecasts of severe and prolonged drouths have great economic value.

DISCUSSION OF TABLES.

Table 1 shows the direction and number of times cirriform clouds were observed at the U. S. Weather Bureau, University of Missouri, Columbia, Mo., during 24 years, 1895 to 1918, inclusive. The observations at this station represent days. As only one observation a day was taken (save beginning with the spring and summer of 1911 and up to 1918) special observations of cirriform clouds were made by the writer; but only one entry for any one direction for one day was made. That is, if cirri were observed five or six times during the day and each observation showed that they were moving from the same direction, only one entry was made for that day; if the direction changed, then each direction was recorded. The prevailing direction at Columbia in winter is from the west, or more probable if a nephoscope had been used, west-northwest. Cirri at this station moving from any point save a westerly one in winter are a rare occurrence indeed. Out of 380 observations only

15 show a movement from other points, viz, south 2, north 8, northeast 1, east 2, and southeast 2. The two times cirri were observed coming from the easterly points were drought years.

In spring the prevailing directions is from the west, or west-southwest. Of a total of 531 observations, all but 49 show cirri from some westerly point. Of the 49 from other points, 37 were from easterly directions, 23 occurring in drought years. The shift to easterly directions becomes more frequent in May. In Table 1 the side marginal notes or remarks on the weather conditions refer to State-wide conditions. It may be noticed that during heavy or normal precipitation cirri travel steadily from some westerly point, generaly from southwest or west. There is but one exception in this record, i. e., May, 1909; but the August following was the driest of its name in 50 years.

In summer the prevailing direction seems to be from west or west-southwest. Of the total 762 observations all but 191 were from westerly points. Of the 191 from other points, 143 were from easterly directions, and all but four occurred during drought years. Two of those four preceded the great drought of 1901.

In autumn the prevailing direction is from the west during September and October, and from west-northwest in November. As during the winter months, one rarely observes the cirriform clouds from any other directions save westerly in autumn. Out of 430 observations all but 17 were from westerly points; of these 17, 3 were from the northeast and 3 from east or southeast.

Table 2 consists of special cloud observations, made at Columbia, Mo., during the severe drought of the summer of 1911. This shows that the higher clouds (probably above 4,500 meters) very nearly boxed the compass for the period entered; and the breaking up of the drought followed the shift of cirri from easterly to westerly directions, or to what usually is considered their normal track. There was no nephoscope at hand, but the observations were taken by the writer, who has been a field meteorologist for more than 30 years, and each observation was verified by his first assistant. From this table we find that from about June 21 to July 6, 1911, a deep easterly wind, probably 5,000 meters deep, was persistent. The surface winds during this time were variable but mostly from points east of south. After July 8, a deep westerly wind prevailed. The surface winds were variable, becoming steady northeast on the 13th, 14th, and 15th. The drought, which had been wide-spread and well-nigh disastrous, was modified by good rains on the 9th and by frequent showers thereafter. The upper current apparently shifted from easterly to westerly on the 8th or 9th. The observations continued daily, but there were no upper clouds observed on the missing dates in the table. It is possible that the upper current changed its course on some date when there was no cirri. In a case like this pilot balloons and theodolites would be invaluable. However, it has been noticed that it requires a day or two for cirri to take up their normal movement in the west after traveling from easterly points. The movement from the east always is slow; after resuming the movement from the west, the traveling at first is slow—a movement that sometimes takes many long minutes to define.

Table 3 gives the direction and number of times cirriform clouds were observed during the time stated at Drexel, Nebr., Aerological Station. This record represents observations and not days, and there were many observations, as a rule, during a day. At this station very few instances are found in which cirri travel out of their normal westerly routes. Out of 2,270 observations all but 56 were observed as coming from westerly points; out of the 56, 17 were from easterly directions; and the phenomenon, similar to the record of Columbia, Mo., appears to be associated with spring and summer seasons, and drought years. When coming from easterly points the winds are deep, as indicated by intermediate cloud movements, similar to Table 2, Columbia. At Drexel a deep northeast wind occurred on March 26, and June 29, 1916; a southeast wind on May 20, 1917, and an east wind on March 22, 1918. Our Columbia record shows that in midsummer the prevailing direction of cirrus clouds is from the west or south of west. The record at Drexel shows that the direction backs to northwest in July and August, at least for these two months for the three years indicated.

Table 4 shows that at times the upper part of the troposphere (the cirrus region) is in a variable state over a great area at the same time.

Drought conditions prevailed in Missouri generally during June, July, and the first seven days of August, 1918. From about July 20 to August 7 the lack of moisture and accompanying heat were well-nigh disastrous to growing crops; but the drought was broken by good rains on August 8 and 9, and frequently thereafter. It is of interest to note that the "prevailing westerlies," as indicated to us by the upper cloud movement, again became practically normal just before the breaking of the drought and continued so, with but slight interruption, during the remainder of the month.

That there appears to be some connection between the reversing of the upper current's usual eastward movement and drought is further brought out by the following résumé:

Year.	Cirriform clouds first observed from easterly points.	Last observed.	Subsequent weather conditions.
1911	In March	July 7	Drouth, May to mid-July.
1912	None observed from easterly		Seasonable summer.
1913	In May	Aug 8	Drouth, May to September.
1914	In May	July 31	Drouth, May to mid-August.
1915	None observed from easterly		Wet season.
1916	In June	Aug. 1	Drouth, last week June to mid-August.
1917	In June	July 4	Drouth, July, confined mostly to central Missouri.
1918	In April	Aug. 5	Drouth, last week May to first week August.
1919	In May		Rainfall June 4–July 8, 52 per cent of average for this period.

During 1919, cirrus clouds were first observed moving from the east on May 29, and since this phenomenon has been observed at this station only during and just prior to periods of drouth, it was believed there would be diminishing rainfall during the summer. For five weeks, from June 4 to July 8 (the date this paper was practically finished) the total rainfall was 2.70 inches, or about 52 per cent of the normal amount, as shown by the following short table, for the State as a whole:

Date.	Rainfall.	Normal.	Departure.
June 4 to 10	0.76	1.00	−0.24
June 11 to 17	0.61	0.81	−0.20
June 18 to 23	0.49	1.01	−0.52
June 24 to July	0.43	1.22	−0.79
July 2 to July 8	0.41	1.13	−0.72
Total for 5 weeks	2.70	5.17	−2.47

All investigators in their studies of the upper clouds have shown that for cirriform clouds to move from an easterly point is an unusual phenomenon. Espy, in

his studies of the easterly motions of the upper current, said he had found that the *true* cirrus clouds averaged scarcely one a year from an easterly direction, and when

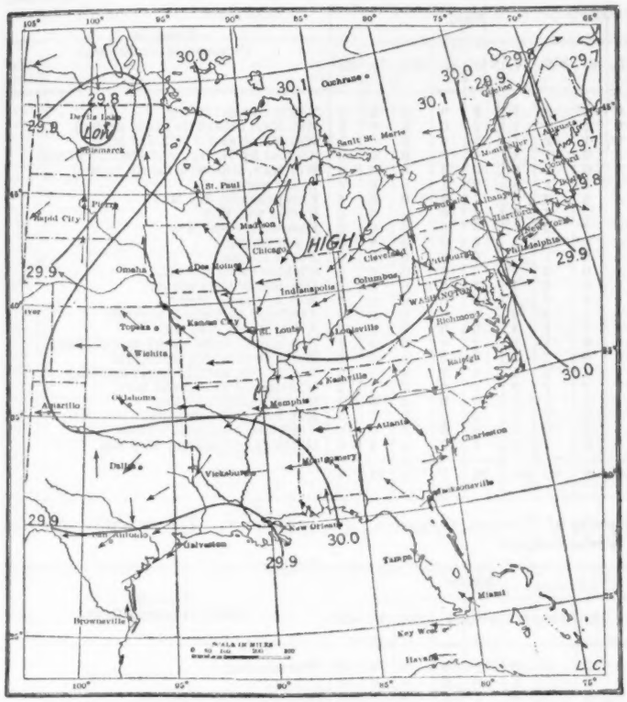


FIG. 1.—Typical pressure distribution accompanying movement of cirrus clouds from the east. (Morning weather map, June 21, 1911.)

they did come from an easterly direction it was only when there was a cyclone of uncommon violence in the east. When assigned to the Gulf Coast, years ago, I observed cirrus clouds from the east when there was a hurricane in the Gulf. Except for this I never have known cirrus clouds to come from the east because of a cyclone to the eastward. In my studies of this phenomenon, I have noticed that cyclones seem to affect the direction of cirrus clouds only a point or two, studied from the latitude of Columbia, Mo. Ferrel[1] writing of the movement of the upper current, states that cyclonic component was merely sufficient, for the most part, to cause deviations of a few points from the usual eastward course, and rarely sufficient to reverse entirely that strong current and give rise to a motion from the east. This also is in accordance with Ley's studies of the motion of the upper current.

I have observed at the Columbia station that whenever the upper clouds are seen to be moving from some easterly point the phenomenon apparently is associated with a certain well-marked pressure distribution, that is, the pressure is high, when averages are considered, over the territory east of the Mississippi and relatively low west of it. (See fig. 1.) While it does appear that the movements of the cirriform clouds are to some extent dominated by a certain type, Hudson Bay summer anticyclone, all summer anticyclones do not have this power. The winter anticyclones, although apparently of great magnitude and influence, do not change the direction, so far as my observations go, of the cirrus clouds save one or two points. It may be, as observed by Ferrel, the easterly motion of the upper current is too strong in winter to be reversed by either the anticyclone or cyclone, although of great depth and power.

Summer, as a rule, is the season when the Hudson Bay anticyclones are at their minimum.[2] But when this rule is broken, when anticyclones come out of the north in June in series, then widespread and more or less severe drouth is probable; and the early effects of the prevalence of the Hudson Bay summer anticyclonic series will be, firstly, a more or less stagnant condition, in a comparative sense, of the upper easterly-flowing current, and secondly, the *cirriform clouds, generally thin in structure, slow of movement, will be coming from the east.* The phenomena may first be noticed as early as March and with increased frequency in May.

[1] A popular treatise on the winds, New York, 1889, p. 308.
[2] E. H. Bowie and R. H. Weightman. Types of anticyclones of the United States and their average movements. MONTHLY WEATHER REVIEW, SUPPL. 4, 1917.

TABLE 1.

Direction of Cirrus or Cirro-stratus clouds at Weather Bureau station, University of Missouri, Columbia, Mo., in winter. The prevailing direction seems to be from the west, or probably more nearly west-northwest.

[This station is in lat. 38° 57'; long. 92° 20'; elevation, 238 meters.]

Direction from, in winter.	December.								January.								February.								Remarks.
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1894–95	0	2	6	3	0	0	0	0	0	0	2	1	0	0	0	0	0	3	4	6	0	0	0	0	
1895–96	0	6	7	2	0	0	0	0	0	3	4	5	0	0	0	0	0	4	5	6	0	0	0	0	
1896–97	0	2	6	2	0	0	0	0	0	3	2	5	0	0	0	0	0	2	3	3	0	0	0	0	
1897–98	0	1	2	3	1	0	0	0	0	0	6	1	0	0	0	0	0	3	2	4	0	0	0	0	
1898–99	0	1	3	2	0	0	0	0	0	2	2	0	0	0	0	0	0	2	3	1	0	0	0	0	
1899–1900	0	0	2	6	0	0	0	0	0	2	3	6	0	0	0	0	0	2	2	4	0	0	0	0	
1900–1901	0	3	0	1	0	0	0	0	0	0	3	1	0	0	0	0	0	0	1	2	0	0	0	0	
1901–2	0	1	4	3	1	0	1	0	0	1	2	6	2	0	0	0	0	0	5	8	0	0	0	0	
1902–3	0	2	0	3	0	0	0	0	0	4	1	4	0	0	0	0	1	5	0	0	0	0	0	0	
1903–4	0	0	4	2	0	0	0	0	0	1	5	1	0	0	0	0	0	1	4	1	0	0	0	0	
1904–5	0	1	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
1905–6	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
1906–7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1907–8	0	0	1	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	1	1	0	0	0	0	
1908–9	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	2	0	0	0	0	1	
1909–10	0	1	1	2	0	0	0	0	0	3	1	2	0	0	0	0	0	0	2	0	0	0	0	0	
1910–11	0	1	0	3	0	0	0	0	0	0	2	1	0	0	0	0	0	0	1	1	0	0	0	0	
1911–12	0	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	
1912–13	0	5	4	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	
1913–14	0	1	1	0	0	0	1	0	0	2	6	1	1	0	0	0	0	1	5	0	0	1	0	0	
1914–15	0	0	2	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	
1915–16	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	
1916–17	0	0	2	1	0	0	0	0	0	2	3	1	0	0	0	0	0	0	2	3	0	0	0	0	
1917–18	0	0	3	2	0	0	0	0	0	1	2	2	1	0	0	0	0	1	4	2	0	0	0	0	
Total	1	31	54	37	4	0	2	0	0	30	53	37	4	0	0	1	1	28	49	44	0	1	0	1	

Direction of Cirrus or Cirro-stratus clouds at the U. S. Weather Bureau station, University of Missouri, Columbia, Mo., in spring. The prevailing movement is from the west.

Direction from, in spring.	March.								April.								May.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895	0	2	3	6	0	0	0	0	0	1	5	3	0	0	0	0	1	5	7	5	0	0	0	0	Nearly normal spring.
1896	0	4	6	4	0	0	0	0	1	7	7	1	0	0	0	0	1	4	4	2	0	0	0	0	Wet May, otherwise about normal.
1897	0	5	1	2	0	0	0	0	0	1	0	1	0	0	0	0	1	2	4	3	0	0	1	1	Wet March and April, dry May.
1898	0	3	1	2	0	0	0	0	0	1	2	1	0	0	0	0	0	1	4	0	0	0	0	0	Normal April, very wet March and May.
1899	0	1	5	1	0	0	0	0	0	1	2	4	0	0	0	0	0	3	8	0	0	0	0	0	Wet May, otherwise nearly normal.
1900	0	1	1	5	0	0	0	0	0	5	1	2	1	0	0	0	0	2	3	2	1	0	0	0	Below normal.
1901	0	1	3	4	0	0	0	0	0	1	2	2	0	1	0	0	0	2	4	1	1	0	0	0	Exceptionally dry May.
1902	0	2	7	4	0	0	0	0	0	2	8	4	0	0	0	0	2	4	3	3	0	0	0	0	Rather wet May.
1903	0	5	0	1	0	0	0	0	0	5	2	3	1	0	0	0	2	10	1	0	0	0	0	0	Excessively wet May.
1904	0	5	2	1	0	0	0	0	0	4	3	1	0	0	0	0	0	3	3	0	0	0	0	0	A wet spring.
1905	0	3	4	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	7	0	0	0	0	0	About normal.
1906	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	4	0	0	0	0	0	Slightly below normal.
1907	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2	1	0	0	0	0	May wetter than normal.
1908	0	1	1	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	1	0	0	0	0	0	Wet April and May.
1909	0	2	2	0	0	0	0	0	0	2	1	1	0	0	0	0	1	2	0	0	0	0	0	2	April and May above normal.
1910	0	0	1	3	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4	0	0	0	0	0	A dry March, wet May.
1911	0	0	2	0	0	2	0	0	0	0	5	0	1	1	0	0	0	1	8	2	0	0	3	1	Dry March, wide-spread drought May.
1912	0	0	1	0	0	0	0	0	0	1	2	2	0	0	0	0	0	7	8	2	0	0	0	0	Rather wet March and April.
1913	0	5	2	0	0	0	0	0	0	3	4	2	0	0	0	0	1	4	5	2	1	1	2	2	Wet March, normal April, dry May.
1914	0	1	4	1	0	0	0	0	1	1	5	1	0	0	0	0	0	2	9	1	0	1	3	2	Widespread drought in May.
1915	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	3	0	0	0	0	0	Exceptionally wet May.
1916	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	May wetter than normal.
1917	0	0	5	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0	0	0	0	0	April wet, otherwise normal.
1918	0	6	6	2	2	0	0	0	0	2	3	1	0	0	2	0	0	4	8	1	2	0	2	0	March dry, April and May wet.
Total	0	47	61	36	2	2	0	0	2	41	71	30	4	2	2	0	9	63	108	25	5	2	11	8	

Direction of Cirrus and Cirro-stratus clouds at the U. S. Weather station, University of Missouri, Columbia, Mo., in summer. The prevailing direction seems to be west, or west-southwest.

Direction from, in summer.	June.								July.								August.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895	1	3	6	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	Wet summer.
1896	0	1	3	4	0	1	0	0	0	1	4	3	0	0	0	0	0	7	2	2	0	0	0	0	Do.
1897	1	3	3	2	0	0	0	0	0	3	2	2	0	0	0	0	0	2	3	1	0	0	0	0	August drier than normal.
1898	1	5	1	4	0	0	0	0	1	3	1	3	0	0	0	1	0	2	5	1	0	0	0	0	About normal summer.
1899	0	7	2	1	0	0	0	0	1	2	5	7	0	0	0	0	0	5	1	0	0	0	0	0	About normal.
1900	1	6	5	2	1	1	0	0	0	7	4	2	0	0	0	0	0	8	2	1	0	0	0	0	Normal.
1901	3	1	5	1	0	0	4	0	0	4	2	1	1	3	3	0	0	1	1	4	1	1	2	0	Severe drought.
1902	0	5	7	3	0	0	0	0	0	10	2	2	0	0	0	0	0	2	5	6	0	0	0	0	Nearly normal summer.
1903	0	3	5	5	0	0	0	0	0	10	3	1	0	0	0	0	0	6	4	0	1	0	0	0	Rather wet.
1904	0	8	5	5	0	0	0	0	0	5	5	5	0	0	0	0	0	2	3	5	0	0	0	0	Do.
1905	0	3	6	0	0	0	0	0	0	0	7	0	0	0	0	0	0	4	6	0	0	0	0	0	Do.
1906	0	5	3	0	0	0	0	0	0	1	8	0	0	0	0	0	0	1	5	0	0	0	0	0	About normal.
1907	0	0	3	0	0	0	0	0	0	1	5	0	0	0	0	0	0	2	2	0	0	0	0	0	Wetter than normal.
1908	0	0	1	0	1	0	0	0	0	0	4	0	1	0	0	0	0	0	2	0	1	0	0	0	July drier than normal.
1909	0	3	3	1	0	1	1	0	0	0	1	1	0	0	0	0	3	0	2	1	0	0	1	0	August driest on record.
1910	0	3	1	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	5	0	0	0	0	0	Above normal.
1911	0	2	2	1	0	3	5	3	0	2	3	2	0	0	5	2	0	1	4	2	0	0	0	0	Drought in June-July.
1912	0	2	3	2	0	2	0	0	1	3	6	2	2	0	0	0	0	2	4	1	0	0	0	0	Drought in July.
1913	1	2	8	1	1	3	5	4	2	0	5	4	1	1	6	3	2	3	5	3	1	3	5	4	Severe drought.
1914	1	5	7	1	0	3	4	4	1	0	3	6	3	2	4	0	0	3	6	2	0	0	0	0	Drought June-July.
1915	0	2	3	1	0	0	0	0	1	0	3	4	0	0	0	0	0	0	1	0	0	0	0	0	Unusually wet.
1916	0	0	5	0	0	1	3	2	0	2	4	0	0	0	8	5	3	1	4	1	0	3	5	4	Drought in July-August.
1917	0	1	4	1	1	1	0	0	0	1	3	3	1	0	2	0	0	0	4	2	0	0	0	0	Dry July; otherwise favorable.
1918	0	4	3	3	0	0	3	0	0	1	6	3	3	5	3	1	1	0	3	1	3	2	4	1	Severe drought, July-August.
Total	9	74	92	41	4	16	25	13	7	58	90	51	12	11	31	12	9	52	79	34	7	9	17	9	

Direction of Cirrus and Cirro-stratus clouds at the U. S. Weather Bureau station, University of Missouri, Columbia, Mo., in autumn. The prevailing direction seems to be from the west during September and October, and from west-northwest in November.

Direction from, in autumn.	September.								October.								November.								Remarks. (State-wide conditions.)
	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	N.	NE.	E.	SE.	
1895	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	October dry, otherwise normal.
1896	0	0	3	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	1	2	0	0	0	0	Nearly normal autumn.
1897	0	0	4	1	1	0	0	0	0	2	1	1	0	0	0	0	0	0	4	3	0	0	0	0	Dry September, extra dry October.
1898	0	2	3	2	0	0	0	0	0	1	1	1	0	0	0	0	0	5	3	0	0	0	0	0	Wet September and October.
1899	0	0	1	4	0	0	0	0	0	2	0	1	0	0	0	0	0	0	1	1	0	0	0	0	About normal.
1900	0	4	2	3	0	0	0	0	1	4	3	0	0	0	0	1	0	0	2	3	0	0	0	0	Not unusual.
1901	1	1	3	2	0	0	0	0	0	2	3	1	0	0	0	0	0	0	1	5	1	0	0	0	Drier than normal.
1902	0	0	4	1	0	0	0	0	0	1	4	2	0	0	0	0	0	2	1	0	0	0	0	0	About normal.
1903	0	5	2	2	0	0	0	0	0	2	2	0	0	0	0	0	0	1	2	2	0	0	0	0	Do.
1904	0	2	4	1	0	0	0	0	0	2	2	1	0	0	0	0	0	1	0	1	0	0	0	0	October-November drier than normal.
1905	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	September exceptionally wet.
1906	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	Dry October.
1907	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	Dry September.
1908	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	Dry September, wet November.
1909	0	3	2	1	0	0	0	0	0	0	3	1	0	0	0	0	0	2	3	4	0	0	0	0	Wet November.
1910	0	1	4	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	2	3	0	0	0	0	Wet September, dry November.
1911	0	2	4	3	0	0	0	0	0	2	5	2	0	0	0	0	0	4	4	3	0	0	0	0	Wet September.
1912	0	4	5	2	0	0	0	0	0	2	6	2	0	0	0	0	0	2	7	7	3	0	0	0	Nearly normal.
1913	0	7	4	2	1	0	0	0	0	3	7	2	0	0	0	0	0	3	3	2	0	0	0	0	September and October wetter than normal.
1914	0	1	3	1	0	0	0	0	1	1	6	3	0	0	0	0	0	2	6	2	0	0	0	0	Wet September, dry November.
1915	0	3	6	2	0	0	0	0	0	2	7	2	0	0	0	0	0	1	4	3	0	0	0	0	Wet September and October.
1916	0	2	7	3	0	0	0	0	0	1	5	2	0	0	0	0	0	2	5	3	0	0	0	0	Dry September.
1917	0	1	6	2	0	2	1	0	0	2	8	3	1	0	0	0	0	3	5	6	0	0	0	0	Dry November.
Total	2	40	73	32	2	2	1	1	2	35	69	26	1	0	0	1	0	29	57	50	4	1	0	0	

TABLE 2.—*Special eye-observation of clouds (approximately 5,000 to over 10,000 meters elevation) at the U. S. Weather Bureau, University of Missouri, Columbia, Mo., from June 21 to July 15, 1911, severe drought period, being much modified, however, on and after July 9, beginning with the shift of the cirriform cloud movements from easterly to westerly direction.*

Date, 1911.	Kind and amount in tenths.	Direction from and time observed.	Other conditions, sky, etc.
June 21	Ci.....Few to 1	ESE..7:30 p. m.–8:30 p. m.	Hot. Brassy sky.
June 22	Ci.....Few to 1	ESE..9:45 a. m.–11 a. m.	Do.
June 22	Ci. Cu.....2 to 5	SE...9:45 a. m.–10:15 a. m.	Do.
June 23	Ci.....Few to 1	ESE..7:45 a. m.–8:20 a. m.	Do.
June 23	A. Cu.....4 to 6	SE...9:45 a. m.–11:55 a. m.	∞
June 24	Ci. St.....1 to 3	ESE..6:30 p. m.–7 p. m.	∞[11:35 a. m., SW.
June 25	Ci. Cu.....1 to 2	ESE..6 p. m.–6:30 p. m.	Hot. Brassy sky.
June 26	Ci. St.....2 to 3	SE...9 a. m.–9:30 a. m.	Hot, dry.
June 26	Ci.....Few	ESE..11:10 a. m.–11:18 a. m.	[11:35 a. m., SW.
June 29	Ci.....Few	ESE..10 a. m.–10:20 a. m.	Hot, dry.
July 1	Ci.....Few to 1	ESE..10 a. m.–10:30 a. m.	Hot. Glaring sky.
July 1	Ci. Cu.....Few to 2	SE...7 p. m.–7:15 p. m.	
July 6	Ci. St.....1 to 3	ESE..7:30 p. m.–8:30 p. m.	Hot and dry.
July 6	A. Cu.....3 to 6	ENE..9 p. m.–10:30 p. m.	
July 8	Ci. St.....1 to 2	SW...6:30 p. m.–7:30 p. m.	Do.
July 9	Ci. Cu.....1 to 3	SSW..10 a. m.–10:30 a. m.	Clear, sultry, a. m. [3:45 p. m.–7 p. m.
July 10	Ci. Cu.....1 to 3	SSW..7:40 a. m.–8:10 a. m.	Bluer sky and lower temperature.
July 10	Ci.....1 to 2	SW...8:30 a. m.–9 a. m.	
July 10	Ci. St.....2 to 4	SW...10:30 a. m.–11 a. m.	
July 10	Ci. St.....4 to 5	SW...3:45 p. m.	
July 10	Ci.....1 to 2	SW...7 p. m.	
July 11	Ci.....Few to 2	SW...8 a. m.–9 a. m.	Sultry.
July 11	A. Cu.....2 to 4	NNW.9:34 a. m.–11 a. m.	
July 11	A. St.....4 to 7	WSW.12:45 p. m.–4 p. m.	0–6°.
July 12	A. Cu.....2 to 3	W....4 p. m.	Blue sky. Cumulus.
July 13	Ci. Cu.....2	WSW.9:15 a. m.	Do.
July 13	Ci. Cu.....5	WSW.9:55 a. m.	
July 14	Ci.....Few to 2	WNW.7:35 a. m.	Do.
July 14	Ci.....Few to 1	WNW.12:45 p. m.	Do.
July 15	Ci.....2 to 3	NW...8:45 a. m.	[–2:16 p. m., W., and 6 p. m., SW.
July 15	Ci.....2 to 3	NW...12 noon	

TABLE 3.—*Direction of Cirrus and Cirro-stratus clouds at Drexel Aerological Station, Lat. 41° 20′ N., Long. 96° 16′ W.; elevation above sea level 396 meters; from Oct. 22, 1915, to Aug., 1918.*

Direction from.[1]	Winter.[2]			Spring.[3]			Summer.[4]			Autumn.[5]			Totals.
	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	
S	0	0	1	0	0	0	6	0	4	0	0	3	S.....14
SSW	1	0	1	0	4	9	10	3	1	3	0	3	SSW.....35
SW	11	6	1	16	6	11	5	12	34	23	20	28	SW.....173
WSW	12	54	22	41	30	35	25	13	25	49	12	18	WSW.....336
W	52	53	81	96	47	60	60	26	17	50	35	30	W.....607
WNW	67	49	61	65	48	41	31	18	19	29	74	80	WNW.....511
NW	53	45	36	63	54	17	25	64	42	17	24	38	NW.....478
NNW	14	0	13	9	9	0	7	9	0	0	3	10	NNW.....74
N	0	0	15	4	1	0	0	0	0	0	0	5	N.....25
NNE	0	0	0	0	0	0	0	0	0	0	0	1	NNE.....1
NE	0	0	0	3	0	0	0	0	0	0	0	1	NE.....4
ENE	0	0	0	0	0	0	4	0	0	0	0	0	ENE.....4
E	0	0	0	4	0	0	0	0	0	0	0	0	E.....4
ESE	0	0	0	0	0	0	0	0	0	0	0	0	ESE.....0
SE	0	0	0	0	0	1	0	0	0	0	0	0	SE.....1
SSE	0	0	0	0	0	3	0	0	0	0	0	0	SSE.....3
	WNW	WSW	W	W	NW	W	W	NW	NW	W	WNW	WNW	W.....607

[1] By nephoscope. [2] Dec., 1915–Feb., 1918. [3] Mar., 1916–May, 1918. [4] 1916–1918. [5] Oct. 22, 1915, to Nov. 30, 1917.

TABLE 4.—*Number of times upper clouds (Ci., Ci.St., or Ci.Cu.) were observed moving from the N., NE., E., etc.*

JANUARY AND FEBRUARY, 1918.

Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Omaha, Nebr.	0	0	0	0	0	8	32	13
Des Moines, Iowa	2	0	0	0	2	2	9	17
Kansas City, Mo.	7	0	1	1	4	17	39	16
Columbia, Mo.	3	0	0	0	0	6	21	8
Springfield, Ill.	0	0	0	0	0	12	23	11
Wichita, Kans.	5	2	0	0	0	22	42	33
Springfield, Mo.	3	0	1	1	4	9	11	9
Nashville, Tenn.	1	0	0	0	0	16	16	8

MARCH AND APRIL, 1918.

Omaha, Nebr.	0	0	0	1	1	4	59	18
Des Moines, Iowa	4	6	4	1	6	5	28	16
Kansas City, Mo.	10	2	0	0	9	22	42	14
Columbia, Mo.	1	2	4	1	2	10	13	4
Springfield, Ill.	1	0	3	0	2	12	27	6
Wichita, Kans.	3	3	3	3	5	26	37	34
Springfield, Mo.	3	5	3	2	7	13	17	2
Nashville, Tenn.	8	7	1	0	7	18	15	5

MAY AND JUNE, 1918.

Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Omaha, Nebr.	0	1	0	0	0	15	66	7
Des Moines, Iowa	2	0	1	0	0	15	26	24
Kansas City, Mo.	5	0	0	0	2	34	42	15
Columbia, Mo.	3	0	1	0	0	15	27	9
Springfield, Ill.	1	0	0	0	4	15	55	14
Wichita, Kans.	1	1	0	0	6	47	45	25
Springfield, Mo.	0	0	0	2	14	23	20	6
Nashville, Tenn.	4	3	1	0	1	11	29	9

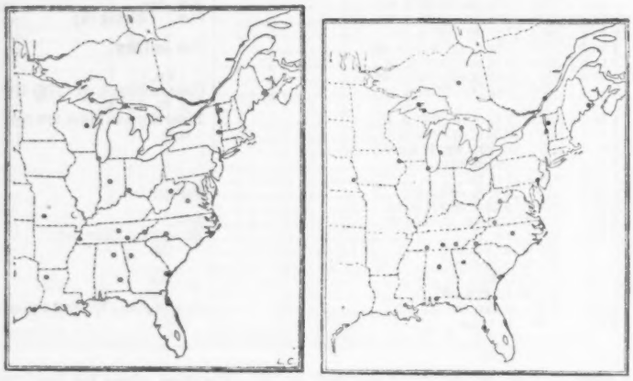
EASTERLY MOVEMENT OF CIRRUS CLOUDS.

By LEON J. GUTHRIE, Meteorologist.

[Dated: Weather Bureau, Fort Smith, Ark., Sept. 27,1919.]

During the period 1909 to 1919, inclusive, cirrus or cirro-stratus clouds were observed moving from an easterly direction at 107 regular or special observations. They moved from the northeast 49 times; from the east, 25 times; from the southeast, 33 times.

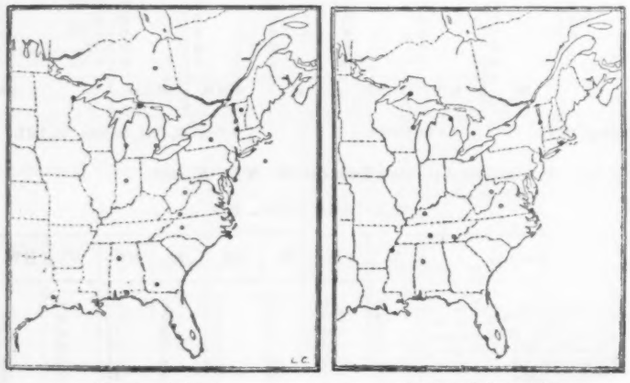
The dates of movement from the northeast were: 1909; April 4, August 3, 5, and 23. 1910; June 18, July 18, 26, 27, and 28. 1911; June 21, July 4, and August 15. 1912; June 28, July 22 and 26. 1913; April 6 May 14, July 8, 23, and August 20. 1914; July 11. 1915; April 15. 1916; July 15, 31, August 4, 19, 20, and 22. 1917; June 9, 28, July 3, 15, 17. 1918; July 4, 5, August 3, 13, September 28. 1919; July 5, 9, 10, 15, September 1, 2, 7, 11.



(Evening before.) (Morning of observation.)

FIG. 1.—Locations of high pressure centers at times of cirrus movements from the NE. at Fort Smith, Ark.

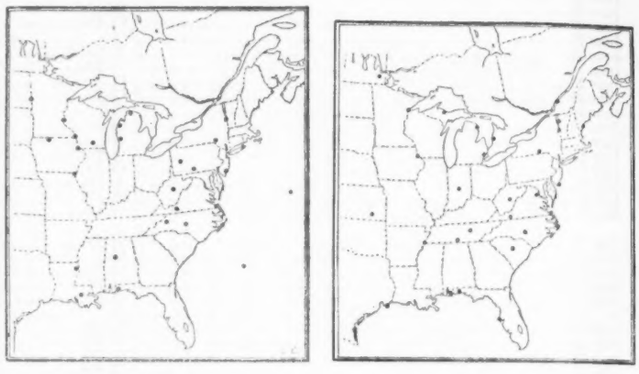
Movement from due east occurred: 1909; April 14, August 13. 1910; July 29. 1911; June 22, July 2. 1912; July 3, 12, August 28. 1913; June 5, September 7. 1914; August 2. 1915; July 12. 1916; July 28, August 16, 18, 21. 1918; August 9, September 27. 1919; June 22, July 7, 8, 31, September 3.



(Evening before.) (Morning of observation.)

FIG. 2.—Locations of high pressure centers at times of cirrus movements from the E. at Fort Smith, Ark.

Movement from the southeast: 1909; August 24, September 4. 1910; June 23, July 13, 15. 1911; July 3, 5, 7. 1912; June 14, July 5, 12, 25, 26. 1914; August 22, September 29. 1915; July 13, 18, 29, September 17. 1916; August 17, 18. 1917; July 23. 1918; March 30. 1919; May 30, June 1, 17, 22, 23, July 2, 30, August 1, September 6.



(Evening before.) (Morning of observation.)

FIG. 3.—Locations of high pressure centers at times of cirrus movements from the SE. at Fort Smith, Ark.

It appears that a well-defined High east of the Mississippi River is necessary to produce the westward movement, as its occurrence has been noted only four times when other conditions obtained. The few exceptions may possibly have been caused by a local condition of unusually active convection. Assuming that the exact location of the Low is of minor consideration, though a trough-like depression extending northeastward from western Texas seems to predominate, attention was chiefly centered upon the location, extent, and development of the Highs.

Charts upon which dots represent the station of highest pressure east of the Mississippi River, on evenings of days immediately preceding, and mornings of days corresponding to the observations, were prepared from the evening and morning Washington weather maps. Separate charts for movements from the northeast, east, and southeast are shown figures 1–3.

Movement from the northeast occurred with HIGHS centered in every State east of the Mississippi River, but the chart shows groupings over the upper Lake Region and in northern Florida and eastern Georgia. Smaller groupings appear in the Ohio Valley and New England.

The chart for movement from due east shows widely scattered centers, with no significant groupings.

For southeasterly movement the groupings shift southward, as might have been expected, congesting along the South Atlantic coast and the eastern Gulf coast. For this direction few centers appear north of the Ohio Valley.

Although, in a general way, the location of the High seems to determine the westward drift, a vast majority of maps that show conditions apparently ideal are not attended by other than the normal westerly movement. But it seems to be an almost invariable rule that when the eastern High develops materially, especially when the pressure increases westward or southwestward through a part, or all, of the lower Mississippi Valley and the middle Gulf States, the phenomenon attends. Numerous maps show this tendency on dates of observed easterly drift. The following dates will suffice for a study of this feature: 1909; April 14–15, August 13–14, August 24–25. 1910; July 12–13. 1911; July 5–7. 1912; July 2–3, July 12–13. 1915: July 18–19, September 16–17.

1916; August 16–18. 1919; June 16–18, July 7–10, September 3–4.

A close study of local conditious on June 22–24, 1919, suggested that marked local convection might temporarily divert the cirrus from a normal path. Active convection during the forenoon of June 22, as shown by highly developed cumuli, was followed, during the afternoon, by a succession of thunderstorms that apparently formed northeast of the station and developed westward and southwestward. True cirrus moved from the east at 7 a. m., 11 a. m., and 12 noon, and cirro-stratus from the southeast at 3.45 p. m., 4.45 p. m., and 7 p. m. Thunderstorm conditions continued through the 23d. On that day the cirro stratus moved from the southeast at 7 a. m., 3.15 p. m., and 6 p. m. Active convection ceased by the morning of the 24th and the clouds returned to their normal drift.

Similar conditions appear to have existed on September 4, 1909, June 23, 1910, June 22, 1911, July 17, 1912, July 15, 1916, and July 28, 1916, but the entire series of observations does not furnish sufficient data for a productive investigation of this feature.

THE WEST INDIA HURRICANE OF SEPTEMBER, 1919, IN THE LIGHT OF SOUNDING OBSERVATIONS.

By R. HANSON WEIGHTMAN, Meteorologist.

[Dated: Weather Bureau, Washington, Dec. 3, 1919.]

The hurricane of September, 1919, is the first well-developed storm of tropical origin in connection with which sounding observations of wind directions and speeds in the free air are available for study purposes. In 1906 and 1907 while Rotch and de Bort were conducting sounding balloon and kite work [1] in the southeastern portion of the North Atlantic Ocean several disturbances of minor importance occurred in the West Indies but, unfortunately, many hundred miles away from the point where observations were being made. Again in the early part of August, 1918, a disturbance of intense character but of very limited extent developed in the Gulf of Mexico and passed inland west of New Orleans during the 6th. The nearest point to the storm at which sounding observations are available is Fort Sill, Okla., about 500 miles distant. On the mornings of the 5th and 6th at this station the winds up to the greatest elevation reached, the 2,000 meter level, were from the SW., 10 to 18 m. p. s., and at noon of the 6th they had backed to SSW. and decreased somewhat in velocity, seemingly unaffected in any way by the disturbance.

In the September, 1919, hurricane upper-air observations are available from three stations in Texas, two in Oklahoma, one in Georgia, and from nine or ten other stations outside of the Gulf States. The most complete series of observations from a point relatively near the hurricane center is from the Leesburg, Ga., station, the nearest point reached by the storm center, however, being about 500 miles. At the time the disturbance was approaching southern Texas, the sky over that region unfortunately became overcast for the most part, thereby preventing the making of observations at greater altitudes than 3.5 km. and in most cases under 2.

Perhaps the most interesting feature brought out by these observations is the rather sudden change in wind direction as shown by sounding balloons at Leesburg. For several days previous to September 5, the winds above 3 km. were from a westerly quarter while near the surface they were between north and east. On the 1st westerly winds were first encountered at the 2 km. level, on the 2d at the 3-km. level, on the 3d at 3-km., on the morning of the 4th they had descended to 2 km. and by evening had risen to 3.5 km. On the morning of the 5th they were first observed at the 4-km. level and by the afternoon of that date were not in evidence up to 11 km., the greatest altitude reached. So far as observations are available, no trace of westerly winds is found until the morning of the 12th, when they were encountered at an elevation of 6 km., and by the afternoon of that date they had descended to 4.5 km. This shift of the upper winds to W. and N. seems to have been of a temporary character, for on the 15th they were generally between ENE. and ESE. up to 11 km., and it was not until the 16th that they changed to steady westerly.

A current from the east was then fully established at Leesburg at all altitudes up to probably 10 km., at least, from the evening of the 5th to the morning of the 12th, a rather unusual occurrence, if we may judge from a casual inspection of the observations made during the two or three preceding months. In the lower strata, at least, this distribution of winds is consistent with the surface barometric distribution, for during the time of the prevalence of the easterly winds pressure was relatively high over the southern Appalachian region and the interior of the east Gulf States and relatively low to the southward. The persistence of the easterly winds in the upper layers, however, appears to be quite unusual. This easterly current is also in evidence up to the 5 km. level at the south Texas stations, i. e., Groesbeck, Ellington Field near Houston, and Kelly Field near San Antonio, from the 1st of the month until the time the hurricane crossed the Gulf coast about 50 miles south of Corpus Christi on the 14th. The highest levels shown by the observations do not exceed 5 km. except in two cases; one on the morning of the 5th at Kelly Field, showed winds between N. and NW. between 5 and 10 kilometers. This easterly current seems to have a rather well-marked limit, for the stations at Broken Arrow and Fort Sill, both in Oklahoma and less than 500 miles to the northward, showed a number of observations between the 5th and 10th of the month, in which the winds were from a westerly quadrant. Likewise, with the easterly winds observed at Leesburg, the northern boundary must have been quite well defined for the sounding observations at Washington about 750 miles distant show practically all winds from a westerly quarter. The southern limit of the easterly current is rather difficult to determine, but an examination of the cloud observations at Swan Island, Belize, and Bluefields shows that easterly winds prevailed in the cumulus level (about 2,000 meters) up to the 8th. During the 4th a minor disturbance passed over Santo Domingo, advanced northwestward to the west of Turks Island by the morning of the 5th, and from that point recurved to the northeastward. On the evening of the 6th after the passage of this disturbance the winds over Jamaica in the cumulus level were southerly, over Haiti southeasterly,

[1] Etude de l'atmosphère marine par sondages aériens; Atlantique moyen et région intertropicale. Par Mm. L. Teisserenc de Bort et Lawrence Rotch. Travaux Scientifiques de l'observatoire de Météorologie Dynamique de Trappes. Tome IV.

and over Porto Rico easterly (see fig. 1), and the wind at Turks Island had backed to the southeast, indicating the presence of a second disturbance to the southwest or westsouthwest of that point. Fig. 1 shows a circulation of considerable extent with S. to SE. winds on the south side and NE. winds on the northwest side, which is the earliest recognizable stage of the hurricane. Figs. 2, 3,

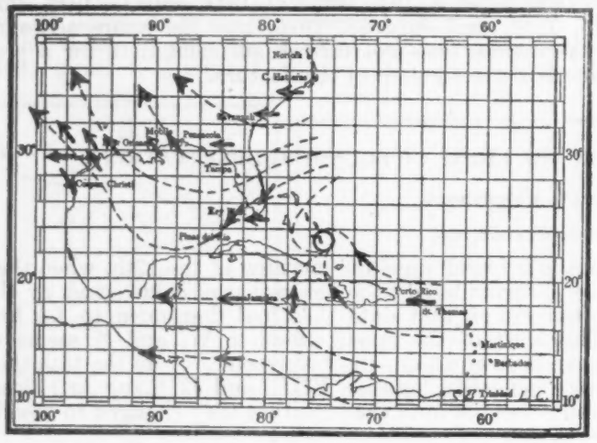


FIG. 1.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 6, 1919.

and 4 show subsequent stages of the storm. The arrows indicate wind directions in the cumulus level (2,000 m.) as obtained from clouds and sounding observations. Instantaneous stream lines[2] have been drawn in order to bring out to the best advantage the existence of the countercurrents to the northwest and southeast of the area

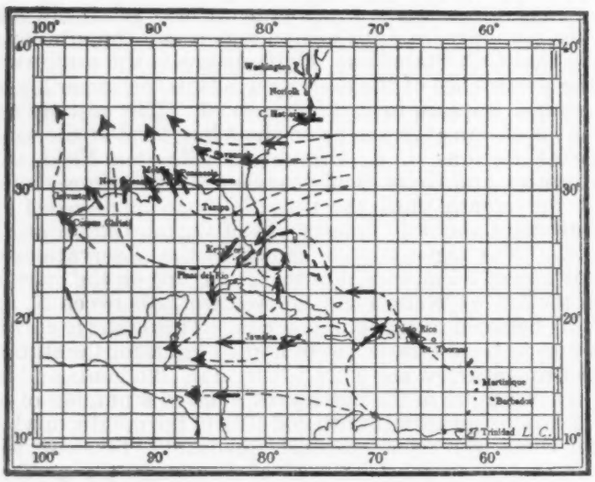


FIG. 2.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 7, 1919.

where the storm developed. The small circles show the center of the hurricane.

On page 6 of MONTHLY WEATHER REVIEW, Supplement No. 4, Anticyclones of the United States and Their Average Movements, it is stated:

> Likewise in the late summer and early fall months of the Northern Hemisphere hurricanes occur in the doldrums, a region flanked on the north by the northeast trades and on the south by the southeast trades, which latter on crossing the Equator and passing to an appreciable north latitude are deflected to the right and become southwest winds.

[2] The Life History of Surface Air Currents. By W. N. Shaw and R. G. K. Lempfertp M. O. 174.

It would seem that the wind conditions depicted on fig. 1 are a good illustration of the principle stated in the above extract.

An inspection of the means of the velocities at Leesburg at the 2,500-, 3,000-, and 3,500-meter levels during the hurricane are shown in fig. 5. These levels were chosen for the reason that it was believed a mean of

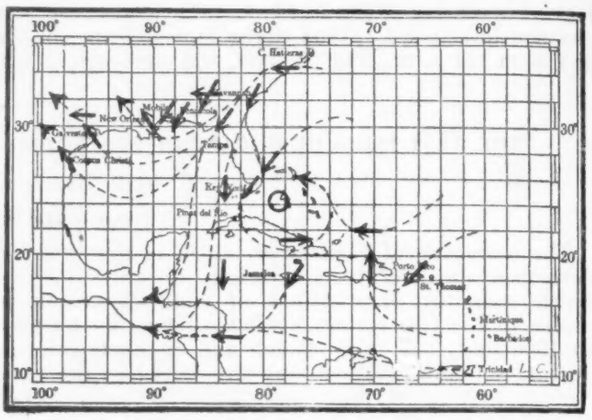


FIG. 3.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 8, 1919.

them would be reasonably representative of the general air movement and secondly they were the highest levels at which a sufficient number of twice daily observations were available. It will be observed that winds were of small velocity, i. e., below 5 m. p. s. previous to the 6th and that from the evening of the 6th to the morning of the 10th they were greatest, averaging about 9 m. p. s., after

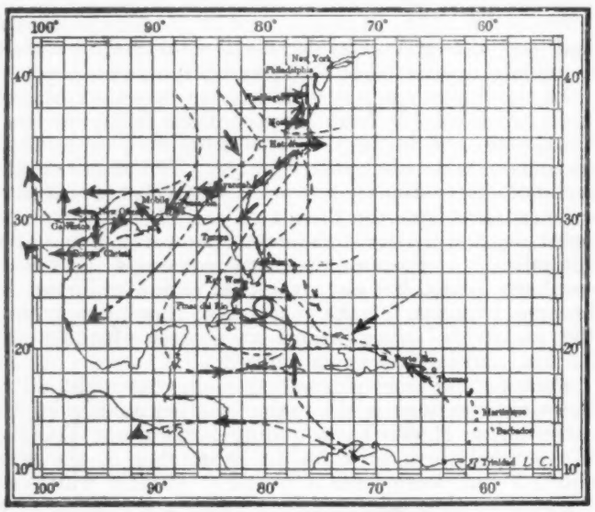


FIG. 4.—Instantaneous stream lines (2,000-m. level), p. m., Sept. 9, 1919.

which time they decreased to less than 6 m. p. s. At its inception the center of the hurricane was about 1,000 miles from the station and on the 10th it was about 500 miles distant. It is rather difficult to explain the fact that during the time the storm was nearest the station and while it was at its maximum development these wind velocities decreased to about half of what they were

when the storm was approaching its nearest point and before it had attained full intensity. However, having in mind the countercurrent theory of storm development, it is interesting to note that the high velocities of these easterly and northeasterly winds—little is available to show directions and velocities south of the center—preceded the increase in intensity of the storm and that a short time after these currents decreased to normal velocities the storm did not further increase in intensity. The storm was able to maintain its destructive violence for about 5 days after the easterly winds at Leesburg had decreased to normal velocities, after which time it

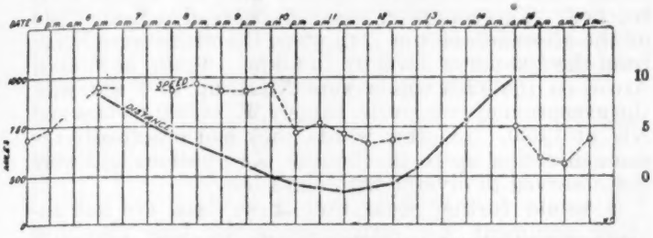


FIG. 5.—Distance of hurricane center from Leesburg, Ga. (solid lines) and mean of wind speeds at 2,500, 3,000, and 3,500 meter levels at Leesburg, Ga. (broken lines).

decreased in intensity. It is believed that, whatever be the cause of the high velocities noted, they were instrumental in causing the storm. The cause of the high easterly winds the writer is at a loss to explain. It has been suggested that the overflow of air from the storm may have had the effect of decreasing the barometric gradients aloft, thereby causing the winds to decrease as the storm approached the station. Observations of the vertical barometric gradients as obtained from the kite observations at Leesburg are somewhat meager. Observations

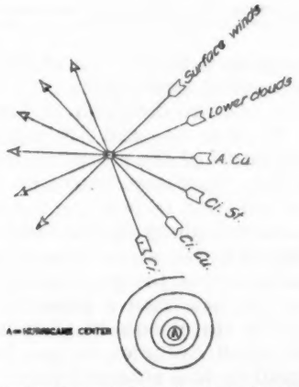


FIG. 6.—Direction of cloud movement with reference to direction of hurricane center.

are, however, available for the 3rd, 5th, 6th, 7th, 13th, and 14th but the gradients on those dates fail to explain the cause of marked increase in the wind velocities from the 6th to 10th and the decrease thereafter, the gradients between the surface and 1,000 meters, 1,000 to 2,000 and 2,000 to 3,000 being practically the same preceding, during, and subsequent to the increase in the winds.

It has been stated in connection with tropical storms that the direction of the winds at different elevations as evidenced by the movement of clouds, forms different angles with the line connecting the point of observation and the storm center.[1] The following extract from Mr. Boyer's paper gives the underlying principle of atmospheric circulation in and around hurricanes as enunciated by Father Vines.

As a rule the lower currents converge, forming with the bearings of the storm center a variable angle which is almost always greater than

FIG. 7.—Instantaneous stream lines (2,000-m.level), p. m., Sept. 11, 1919.

a right angle. * * * The lower clouds in the interior of a hurricane fly ordinarily in directions perpendicular to the bearings of the center. * * * The cumulus (high) (alto-cumulus?), cirro-stratus, cirro-cumulus and the cirrus clouds that precede the hurricane generally diverge, that is to say their direction forms with the bearings of

FIG. 8.—Instantaneous stream lines (4,000-m. level), p. m., Sept. 11, 1919.

the center an angle less than 8 points (90°) with the very noticeable peculiarity that if different strata are observed it will be seen that the divergence increases with elevation.

Fig. 6 which appears in both papers referred to shows the relative directions at the different levels. To test the

[1] Atmospheric circulation in tropical cyclones, as shown by the movement of clouds H. B. Boyer, Washington, 1896. U. S. Weather Bureau publication, and West Indian Hurricanes, Benito Vines, Washington, 1898. U. S. Weather Bureau publication No. 168.

application of these principles to a storm in the Gulf of Mexico around which numerous observations are available, charts were prepared for several dates using the cloud observations and sounding observations, it being consid-

FIG. 9.—Instantaneous stream lines (6,500-m. level), p. m., Sept. 11, 1919.

ered that certain kinds of cloud were representative of certain elevations and four levels were adopted as follows:

Meters.	Cumulus.	Strato-cumulus.	Alto-cumulus.	Alto-stratus.	Cirro-cumulus.	Cirro-stratus.	Cirrus.
2,000	1,585	2,123					
4,000			3,656	4,572			
6,500					6,096	6,706	
8,500							8,534

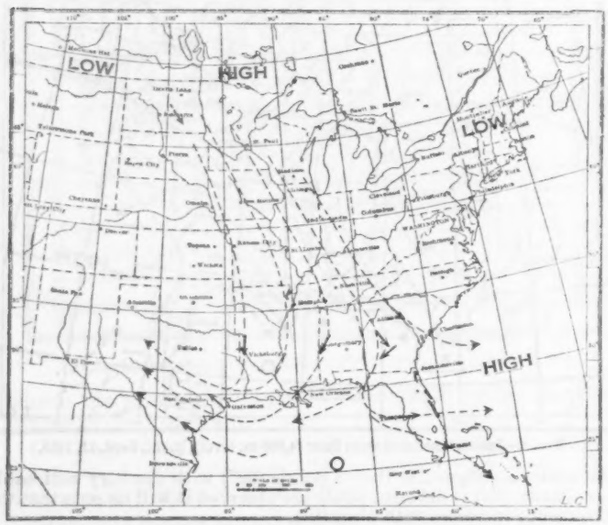


FIG. 10.—Instantaneous stream lines (8,500-m. level), p. m., Sept. 11, 1919.

The afternoon sounding observations were used together with the clouds recorded at 8 p. m., 75th meridian time, and when clouds were not available at that observation those observed at noon were employed, the 8 p. m. and noon observations being separated by a nearly equal time interval from the sounding observations. The maps of September 11 are reproduced in figs. 7, 8, 9 and 10. From an inspection of these charts on which instantaneous stream lines have been drawn and on which the center of the hurricane is indicated by a small circle, it is apparent that the principles set out by Boyer and Vines are not entirely applicable to this storm, however well they may be adapted to conditions in the West Indies—nor do the charts for other days change this point of view. In this connection it is a fact that the winds at Leesburg on the morning of the 9th were NE. at every level from the surface up to 5 km. and NNE. at 6 km., the greatest reached, and on the afternoon of the 9th winds were NE. or ENE. up to 7 km., the highest level reached. This condition was also observed at Kelly Field on the afternoon of the 11th when the winds were NNE. from the 500-meter level up to 6 km. Again, at Broken Arrow on the 12th winds were NNE. up to 7 km. with the exception of two levels, namely, E. at 500 meters and NE. at 1,000. In other words, they had practically the same direction up to the limit of observations and were not observed to diverge with elevation.

It would further seem that these data are but another argument for setting aside the long cherished

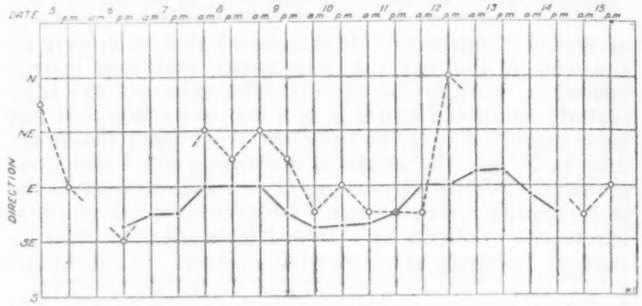


FIG. 11.—Direction of movement of hurricane (solid lines) and mean of wind directions at 2,500, 3,000, and 3,500 meters at Leesburg, Ga. (broken lines).

theory that in cyclones there is an outflow in the upper strata which is in effect anticyclonic.

Fig. 11 shows the wind direction at Leesburg, a mean being taken of the 2.5, 3.0, and 3.5 km.-levels, and the direction of movement of the storm center each 12 hours. It will be seen that they correspond in quite a marked degree, which would seem to indicate not necessarily that the storm was carried along in the drift of the easterly winds but rather that the storm passed westward along the southern boundary of the great easterly current.

The following extract from a paper by H. H. Hildebrandsson[4] refers to statements by Clement Ley concerning the movement of cyclones in the Northern Hemisphere is pertinent in this connection:

> However, if the steepest gradients are found to northwest, north or northeast of the center, it (the cyclone) most frequently remains motionless or moves (evidently slowly) in any direction, although a movement toward the west, which should then be found, is in reality relatively rare.

The movement of the September, 1919, storm was unusual in direction and in rate of movement, and, further, pressure was relatively high to the north of the center. The movement was unusual in that storms originating north of the Islands generally move north and northeastward, and the rate of movement was abnormally slow, in fact only about 200 miles a day, whereas the average for September storms approximated 250 miles a day, that is only about four-fifths the usual rate.

[4] MONTHLY WEATHER REVIEW, June, 1919, 47: 375.

INTENSE RAINSTORM OF OCTOBER 4, 1919, AT DUBUQUE, IOWA.

On October 4 Dubuque was again visited, for the second time during 1919,[1] by a rainstorm of great intensity. The fall within an hour (2.66 inches) has been exceeded since the beginning of record 46 years ago only by the storm of July 9, 1919, and probably by the storm of July 4–5, 1876. The storm of October 4 gave a total of 3.38 inches, as compared to a total of 3.87 inches on July 9. Rainfall was not remarkable on either date for "total" amount, but for intensity of fall within an hour.

The great downpour occurred between 3.13 p. m. and 4.39 p. m., 90th meridian time, and was preceded by and followed by light rain. Rainfall was excessive from 3.18 p. m. until 4.38 p. m., and accumulated amounts during this period were as follows:

	Inches.		Inches.
5 minutes	0.15	35 minutes	2.18
10 minutes	.35	40 minutes	2.33
15 minutes	.70	45 minutes	2.44
20 minutes	1.27	50 minutes	2.54
25 minutes	1.63	60 minutes	2.66
30 minutes	1.98	80 minutes	2.97

The following table gives the greatest amount of rainfall in 5, 10, 15, 30, 45, 60, and 120 minutes during the storm of October 4, as compared with the storm of July 9, 1919:

Greatest amount in—	Storm of July 9.	Storm of Oct. 4.
	Inches.	*Inches.*
5 minutes	0.80	0.59
10 minutes	1.20	.96
15 minutes	1.52	1.35
30 minutes	2.23	2.06
45 minutes	2.64	2.43
1 hour	2.70	2.66
2 hours	3.03	3.06

The storm of October 4 was more local in character than that of July 9, and the area of heavy rainfall did not extend to Union Park, where great damage resulted on July 9. Intense rainfall, however, fell over the entire city, causing great damage to brick pavements on waterway streets. The effects of the storm within the city limits were practically a repetition of what occurred on July 9.

The brick surface of Eighth, a steep waterway street, was again ripped off for several blocks. Seventeenth and Twenty-second Streets experienced similar damage as on Eighth, though much less steep. Seventeenth was not much damaged on July 9. Kaufmann Avenue was in process of repaving due to damage from the storm of July 9, and much of the new work was ruined as before, causing heavy loss to the contractor. East of Clay and north of Sixteenth a flat, residential section two or more blocks wide and more than a mile long became a temporary lake during the storm and scores of cellars in this section were flooded and considerable property damaged.

There was other damage of a less serious nature in various parts of the city. The bathing beach property at Eagle Point, for instance, was much damaged for the third time this season. Losses outside the city were not heavy. Four small county bridges were damaged or destroyed by freshets, the loss amounting to about $3,000.

The total loss from this storm is estimated at about $60,000, at least two-thirds of which amount was to city streets. Fortunately, in this storm no lives were lost, as on July 9.—*J. H. Spencer.*

[1] See MONTHLY WEATHER REVIEW, July, 1919, 47; 468.

SOME BROADER ASPECTS OF RAIN INTENSITIES IN RELATION TO STORM-SEWER DESIGN.

By ROBERT E. HORTON.

[Abstracted from Municipal and County Engineering, June-July, 1919, 4°, 12 pp., 16 figs.]

Owing to the large number of rainfall intensity formulæ which are used in various localities in storm-sewer design, the author was led to make a study of them, with special relation to the underlying physical and meteorological causes of excessive rainfall. After defining the terms "rainfall rate" and "rainfall intensity" and pointing out the distinction of the two terms, namely, that "rate" implies quantity per unit of time, whereas "intensity" implies a quantity in a given time interval, the author explains the notation employed in formulæ and gives the several types into which these formulæ have fallen. The mechanism of the thunderstorm is then discussed, together with the character of the rainfall rates of different types of storms, tropical rainfall, and the frequency curves of excessive rains in New York. The following are some of the conclusions:

1. Excessive rain intensities for short-time intervals mostly occur in thunderstorms, or in storms of the thunderstorm type.

2. Rainstorms producing maximum intensities are mostly the result of violent convection.

3. The occurrence of thunder affords quite positive proof of the existence of suspension storage, and the sudden precipitation of such storage is probably a usual cause of high rain intensities for short intervals of 5, 10, or 20 minutes.

4. High rain intensities for longer intervals are probably due to storm gusts or pulses.

5. High rain intensities for long periods are result of general cyclonic conditions.

The writer has not attempted in this article to give definite formulæ of general applicability for the expression of the relation between rain intensity, duration, and frequency. It is hoped that the results given will suggest and encourage further study along similar lines, such as may afford a more complete basis for generalization.

The requirements for a rain intensity formula based on investigations thus far made may be stated as follows:

(1) It should indicate a finite intensity for zero duration and for the minimum exceedance frequency.

(2) For a given duration the rain intensity should approach a finite maximum or limiting value as the exceedance interval increases.

(3) The maximum or limiting value should decrease as the duration interval of the rain increases.

(4) A single general type of formula should be applicable ovel extensive geographic areas and to regions varying in amount of seasonar precipitation and thunderstorm frequency.

(5) The formula may contain constants whose values in turn can be expressed either in terms of unit rain intensity, thunderstorm frequency, or total precipitation during the thunderstorm season.

(6) The form of expression should be such as to give the required intensity in terms of duration and exceedance interval, so that when the constants are known for a given location intensities of varying duration, but of the same frequency, can be determined directly on the one hand, or intensities of the same duration, but of varying exceedance intervals, can be obtained directly on the other hand."

The paper affords an admirable example of one of the points where the engineering profession and the science of meteorology meet; indeed, where meteorology is indispensable.—*C. L. M.*

INTENSITY OF PRECIPITATION.

The intensity, or rate, of rainfall varies from zero up to several inches per hour, and, like the strength of the wind, has been popularly divided into several, more or less definite, grades. Most of these, together with the roughly averaged values they imply, are given in the accompanying table.

Precipitation values.

Popular name.	Precipitation intensity, mm. per hour.	Milligrams liquid water per liter of air.	Velocity of fall, meters per second.	Height of cloud, meters above surface.
Clear	0.00	0.00		
Fog	Trace.	0.60	0.003	0
Mist	0.05	5.55	0.25	100
Drizzle	0.25	9.26	0.75	200
Light rain	1.00	13.89	2.00	600
Moderate rain	4.00	27.78	4.00	600
Heavy rain	15.00	83.33	5.00	1,000
Excessive rain	40.00	185.19	6.00	1,200
Cloud-burst	100.00	540.14	7.00	1,200

—*W. J. Humphreys.*

THE WATER CONTENTS OF THE ATMOSPHERE IN RELATION TO HEAVY RAINFALLS.

W. H. Dines has published in the October, 1918, number of the Symons's Meteorological Magazine, a summary of the usual water contents of the atmosphere in western Europe, as determined by the humidity records of 250 registering balloons.

Mr. Dines says:

In the winter the total equivalent rainfall is about 0.40 in., with a range from 0.25 in. to 0.80 in.; in summer the mean is about 0.80 in., with a range from 0.50 in. to 1.50 in. The amount seems to depend chiefly on the temperature and but little on anything else, i. e., if the air is warm there is almost certain to be plenty of moisture and conversely. Practically all the water is contained in the first few kilometers.

These amounts, which would be precipitated if all the moisture present in the atmosphere over a place were condensed, are small relative to those which might result from the inflow of moisture which occurs in the usual convergence of winds in a cyclone. Taking as an example a circular area of 100 kilometers radius, a wind 500 meters deep and having an inflowing component of 10 meters per second would bring in the course of 24 hours sufficient moisture to produce about 8.6 inches (220 mm.) if the temperature were 80° F., 6.6 inches (160 mm.) at 70° F., 3.2 inches (80 mm.) at 50° F., and 1.5 inches (40 mm.) at 30° F. If the circular area were 100 miles in radius and if the inflowing component of the wind were 10 miles per hour, these values would be about quartered. The actual rainfalls would be less, for some of the moisture remains when the air flows away from the area aloft. If the air should be cooled 30° F., as it would in ascending about 2 miles, the precipitation would be about a third less. Since the air which goes into a cyclone does not rise uniformly about the center, the rainfall rate may easily be doubled over considerable areas, at the expense of that over other areas. If a cyclone, however, is moving, this difference in rate might not show in the distribution of total rainfall.—*C. F. B.*

PANAMA THUNDERSTORMS.

By H. G. CORNTHWAITE, Asst. Chief Hydrographer.

[Dated: Balboa Heights, C. Z., October, 8, 1919.]

SYNOPSIS: Thunderstorms in Panama are of frequent occurrence during the eight rainy-season months. More occur over the interior than along either coast, and generally more occur in the afternoon than during the night or early morning.

Thunderstorms are more numerous in Panama than anywhere in the United States, averaging from 100 to 140 per year, but the total loss of life and property damage is relatively less in Panama than in many sections of the United States, probably due to (1) electric discharges between clouds, failing to reach the earth, (2) numerous uninhabited hilltops serving as conductors and protecting the inhabited valleys, and (3) atmospheric conditions favorable for ready interchange of electric currents, tending to prevent the accumulation of powerful electric stresses or differences of potential.

INTRODUCTION.

Thunderstorms are of frequent occurrence in most tropical and equatorial regions of heavy rainfalls. In Panama the curves of thunderstorm frequency follow fairly closely the curves of average monthly rainfall, but August is generally the month of maximum thunderstorm frequency while May and November are the months of heaviest rainfall. There is a marked decrease in thunderstorms in November and December due to a decrease in the number of afternoon convective showers, yet November is usually the *rainiest* month of the year.

The following table shows the yearly average number of thunderstorm days at stations in the Canal Zone, compared with selected stations in the United States:

Station.	Location.	Approximate elevation.	Years of record.	Thunderstorm days each year.
		Feet.		
Colon	Atlantic coast	10	11	106
Culebra	Continental Divide	400	7	137
Balboa Heights	Pacific coast	100	13	119
Tampa, Fla	Gulf coast	67	10	94
Santa Fe, N. Mex	Rocky Mountains	7,013	10	73
Chicago, Ill	Great Lakes	595	10	40
New York City	Atlantic coast	314	10	28
San Francisco	Pacific coast	155	10	1

From an inspection of the accompanying fig. 4 it will be seen that Panama thunderstorms are most numerous in the interior near the Continental Divide and fewest along the Atlantic coast.

HOURLY DISTRIBUTION OF THUNDERSTORMS.

Sufficient data are not available to show accurately the curves of hourly distribution of thunderstorms in Panama, but in a general way from 75 per cent to 80 per cent of all thunderstorms occur in the daytime on the Pacific coast and over the interior, while along the Atlantic coast nearly half of the thunderstorms occur during the night or early morning. The reason for this difference in thunderstorm distribution is to be found in the character of prevailing rainstorms. On the Pacific coast and over the interior most of the rains are afternoon local showers of convective origin, usually accompanied by thunder and lightning, while along the Atlantic coast the climate more closely resembles the marine type and much of the rainfall comes in the form of general storms of wider extent,

[To face p. 723.]

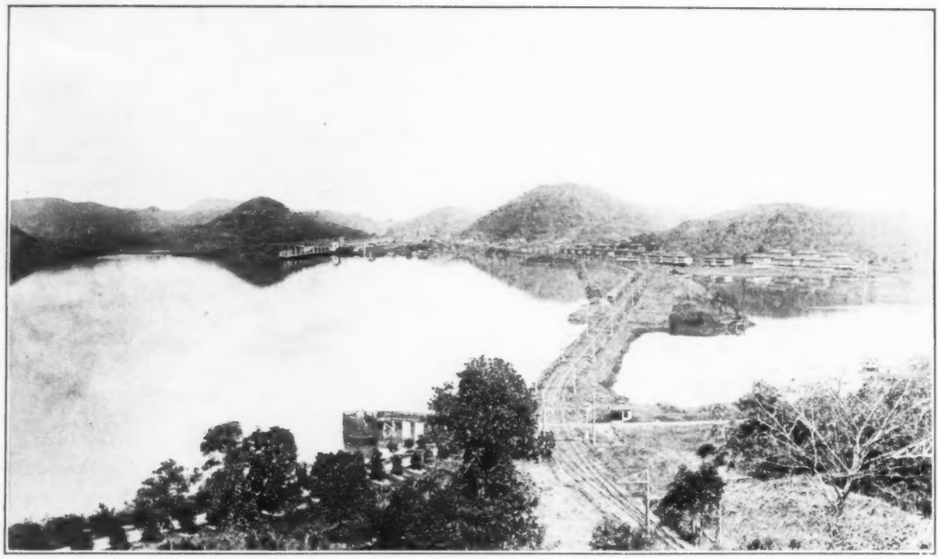


FIG. 1.—Hilly topography surrounding Miraflores Lake. Typical Canal Zone topography. (Photo by H. G. Cornthwaite.)

FIG. 2.—Rainstorm sweeping across Gatun Lake. Note the decaying jungle forest partly submerged in Gatun Lake. The forest died quickly when the lake was filled. (Photo by H. G. Cornthwaite.)

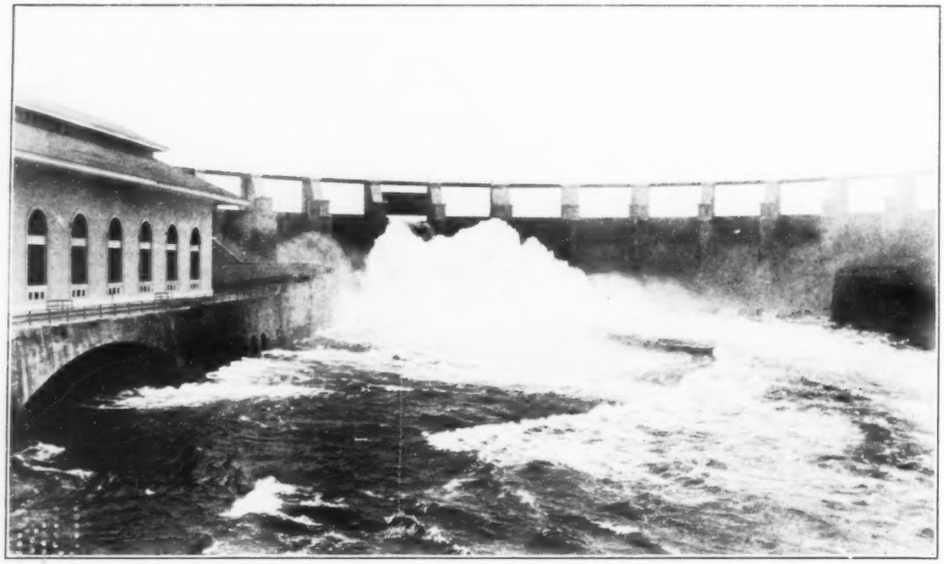


FIG. 3.—Flood waters from excessive rains discharging through the spillway at Gatun. At times the flood discharge into Gatun Lake exceeds the rate of 100,000 c. f. s. View shows 12,000 c. f. s. discharging. (Photo by H. G. Cornthwaite).

many of which occur during the night or early morning. In the Tropics night and early-morning thunderstorms seem to prevail over *ocean areas* and afternoon thunderstorms predominate over *land areas*.

ATTENDANT PHENOMENA.

Precipitation.—Practically all Panama thunderstorms are accompanied by rainfall, many of the rains being at an excessive rate. The average number of excessive rains per year is about 60 on the Atlantic coast and about 30 on the Pacific coast. Most of these excessive rains accompany thunderstorms, but not all thunderstorms are accompanied by excessive rainfall. (Excessive rains are classified in accordance with the United States Weather Bureau scale of excessive precipitation.) See figures 2 and 3.

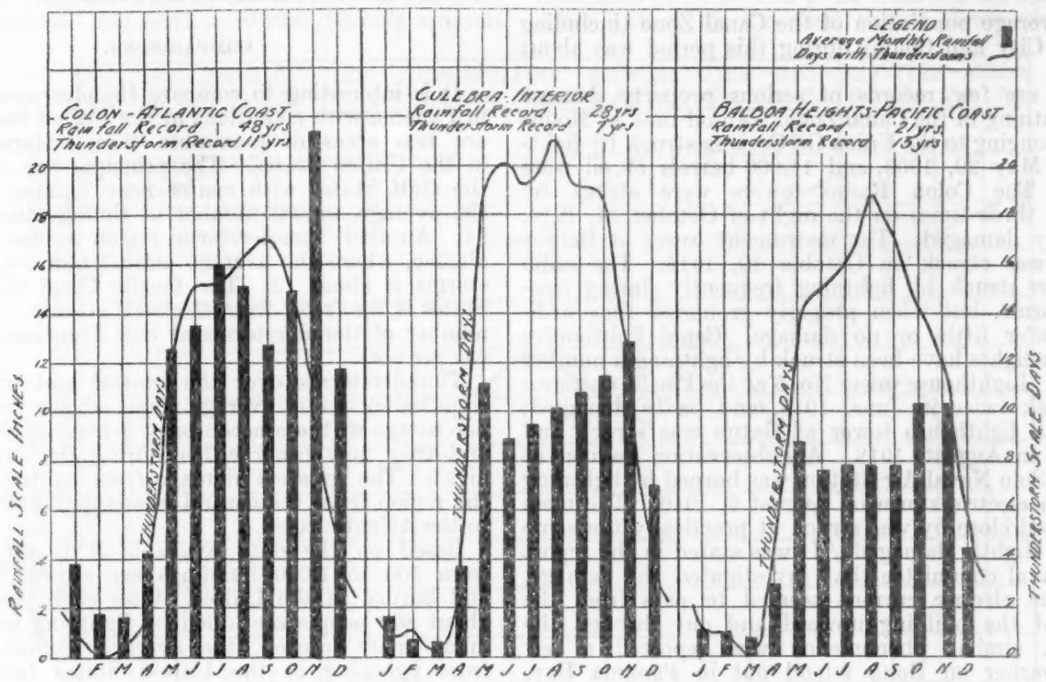


FIG. 4.—Average number of days with thunderstorms compared with average monthly rainfall at Canal Zone stations.

Wind squalls.—Thunderstorms in the Canal Zone frequently are accompanied by wind squalls. These usually have a moderate gyratory motion, but the strongest wind is a straight blow or outrush of air. The wind may blow from any direction. Maximum wind velocities range from 25 up to 45 or 50 miles an hour. These windstorms seldom are of sufficient violence to do much damage on land, and they never are of long enough duration to kick up a heavy sea at either Canal entrance.

Thunderstorms and wind squalls usually travel across the Isthmus from the Atlantic coast toward the Pacific approximately in the direction of the general air circulation, which is from the north or northeast toward the south or southwest. Occasional thunderstorms have been observed to travel in the opposite direction, from the south or southeast toward the north or northwest. Two of the severest windstorms of record in Panama moved across the Isthmus from the southeast. One occurred on July 10, 1909, with a maximum wind velocity of 59 miles an hour from the south at Ancon, and the other occurred during the night of June 16–17, 1919, the maximum velocity recorded being 50 miles an hour from the south at Gatun.

Hail.—Hail has been observed in the Canal Zone or vicinity on three occasions during the past 12 years, accompanying thunder or rain storms. Hail fell at Cucuracha (near Culebra) in 1908, the exact date being unknown, and again at Alhajuela on the afternoon of May 28, 1910. A third hailstorm occurred on Naos Island on June 15, 1912, during a heavy rainstorm. The hailstones that fell during these storms were small and melted quickly, and in no case was the fall excessive. This phenomenon is unusual in a low-lying tropical country, but severe hailstorms are experienced frequently at high altitudes in mountainous regions in the Tropics.

Severe thunderstorms.—Although thunderstorms are very numerous in Panama, averaging from 100 to 140 per year, very few of these storms are particularly severe. Perhaps not more than two or three extremely severe thunderstorms will occur during the course of a year. Contrary to the popular belief that thunderstorms in equatorial regions are something terrific, it is the writer's observation that thunderstorms in the central and upper Mississippi Valley sections of the United States, while not nearly so numerous as thunderstorms in Panama, are frequently more severe and destructive.

LIGHTNING DAMAGE.

Lightning accompanying thunderstorms has caused little damage or loss of life in the Canal Zone and vicinity during recent years. The following table shows the number of deaths by lightning since 1906, taken from the

Health Department vital statistics and from newspaper reports:

Year.	Deaths from lightning.	Year.	Deaths from lightning.
1906		1914	1
1907		1915	
1908	[1] 2	1916	
1909	1	1917	
1910		1918	1
1911	3		
1912		Total (13 years)	8
1913			

[1] Deaths from dynamite explosion set off by lightning.

The average population of the Canal Zone (including Panama City and Colon) during this period was about 120,000.

There are few records of serious property damage from lightning in the Canal Zone. An oil tank at Mount Hope belonging to the Union Oil Co. was struck by lightning on May 20, 1906, and 11,000 barrels of oil were burned. The Colon Radio towers were struck by lightning three times on the night of October 14, 1914, and badly damaged. The instrument tower at Balboa Heights was struck on October 19, 1914. The radio towers are struck by lightning frequently during electrical storms, but when properly grounded they ordinarily suffer little or no damage. Canal lighthouses and range lights have been struck by lightning a number of times. Lighthouse tower No. 5 at the Pacific entrance was struck twice in June, 1918, and badly damaged; and a tall lighthouse tower at Gatun was struck and damaged in August, 1918. An observation balloon at the Coco Solo Naval Air Station was burned by lightning during an electric storm on August 5, 1919. The mess hall located close by was struck at practically the same time and slightly damaged. It was stated in the report of the naval committee that investigated the damage, "That the electric current seemed to pass from the bottom of the building upward and out through the roof." A similar phenomenon was reported a few months earlier on Bona Island out in Panama Bay, where the reinforced concrete lighthouse tower was struck by lightning, the charge seeming to pass from the base of the tower upward and out into space.

The relatively slight damage from lightning suffered in the Canal Zone and vicinity may be partly explained as follows:

(1) A large percentage of the lightning bolts probably never reach the earth, but merely pass from one cloud to another.

(2) In the Canal Zone and vicinity there are a large number of hills with round, conical tops, ranging in elevation from a few hundred feet up to 1,000 feet or more. These hilltops probably serve as lightning rods or conductors, and, being for the most part uninhabited, lightning bolts that strike them do no damage.

(3) It is probable, also, that the humid atmospheric conditions and frequent rainstorms that prevail on the Isthmus and the moist condition of the soil facilitate the ready interchange of electrical currents between the atmosphere and the earth, thus tending to prevent the *accumulation* of powerful electric stresses, or differences of potential, that would finally find relief in *severe* thunderstorms. This is thought to be one of the *principal causes* of the relatively slight damage suffered in the Canal Zone from electric storms.

COMPARISONS.

It is interesting to compare thunderstorm conditions in Panama with conditions in the United States. There are two areas of maximum thunderstorm frequency in the United States. The principal one extends over the Gulf States with center near Tampa, Fla., where the average annual number of thunderstorms is about 94. Another thunderstorm region centers over New Mexico, where the average annual number of thunderstorms is about 73. The Pacific Coast of the United States is the freest from electrical storms. The average number of thunderstorms at San Francisco is *less than one per year*.

Thunderstorms over the central and upper Mississippi Valley States average about 40 per year. A large percentage of these accompany general cyclonic storms, and they may occur either during the daytime or at night. The greatest damage from lightning occurs in the region from the central Mississippi Valley eastward to the Atlantic coast.

Based on the data available it is estimated that from 500 to 1,000 buildings are struck by lightning and burned in the United States each year, and that about 800 people are killed by lightning annually, and many more injured, the average annual death rate from lightning in the United States being approximately one per 120,000 population.

It would seem that although thunderstorms are more numerous in Panama than anywhere in the United States, the total loss of life and property damage from electric storms is relatively less in Panama than in many sections of the United States.

The data on United States thunderstorms presented above were abstracted from papers on thunderstorms, by W. H. Alexander, of the United States Bureau, and Robert DeC. Ward, published in the Proceedings of the Second Pan-American Scientific Congress, Vol. II.

NOTE ON PILOT-BALLOON FLIGHTS IN A THUNDERSTORM FORMATION.

By LIEUT. IVAN R. TANNEHILL.

[Dated: Fort Story, Va., Nov. 14, 1919.]

At Fort Monroe, Va., on August 30, 1919, at 3:00 p. m., a thunderstorm formation in the southwest appeared to be moving toward the northeast. This storm passed over the Fort with wind shifting to northwest at the surface at 4:01 p. m. Rain began lightly at 4:38 p. m. and later became heavy. Six pilot-balloon observations were made in front of, and under, the cloud. This note is a brief summary of those observations.

During the day the wind in the lower levels was brisk from the southwest and south-southwest, turning counterclockwise. The velocity decreased rather rapidly aloft to a height of 1,000 meters, the decrease being most marked at 800 meters elevation. This probably occurred chiefly toward the time of the third observation at 3:00 p. m. Figure 1 shows the velocity and direction of the wind during the day up to 3:00 p. m., for heights in 200-meter intervals.

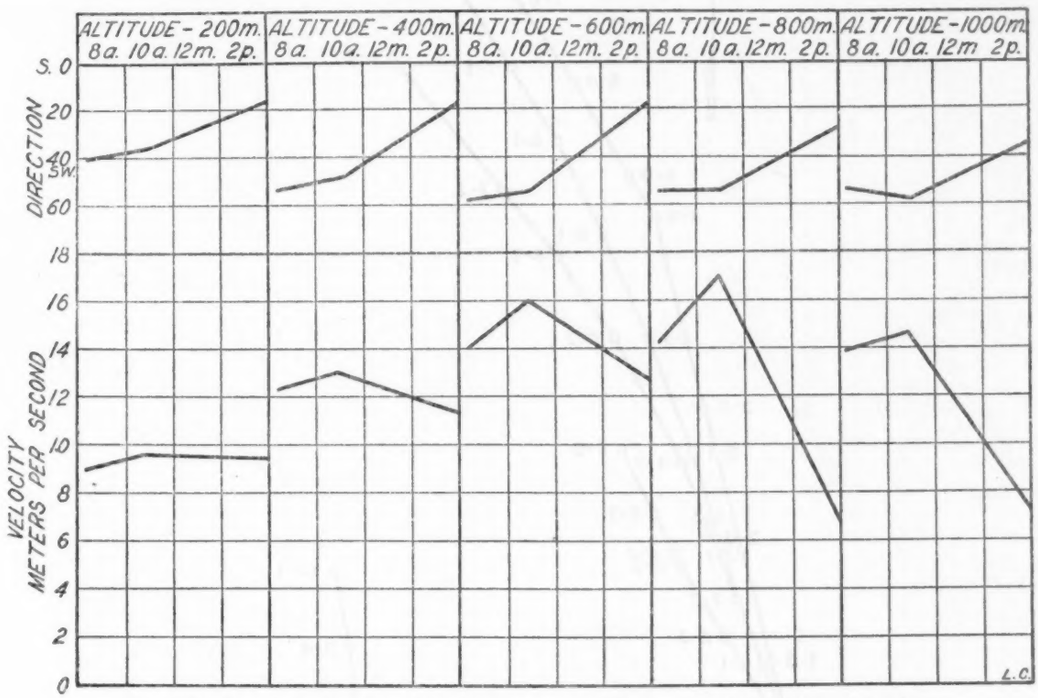


FIG. 1.—Velocity and direction of the wind during the day up to 3:30 p. m., for heights in 200-meter intervals.

At 3:00 p. m. the pressure was 29.87 inches (sea level) and the temperature was 31° C. Upper-air observations were being made with one theodolite, but when it appeared that the thunderstorm would pass near the Fort men were sent to the distant station and two-theodolite observations were begun at 3:45 p. m.; base line 1,541 meters, azimuth 201°.

Until time of wind shift the balloons moved along the base line so that altitudes computed are not sufficiently accurate to represent in detail the vertical movements of the air. After wind shift the vertical movements appeared to be quite irregular.

The six observations were taken at 3:00, 3:30, 3:45, 3:55, 4:03, and 4:15 p. m. The horizontal projections of the paths of these balloons are given in fig. 2. During this time the storm passed over the station and the wind shifted. At 3:00 p. m., there was intermittent thunder, nearly continuous. At 3:15 p. m., the top of the cumulus had mushroomed, had extended to the zenith, and was drifting rapidly toward the northeast. At 3:30 p. m., squall clouds were moving in from the southwest. At 3:45 p. m., there were upper clouds over the entire sky and the squall clouds reached the zenith. At 4:01 p. m., the wind shifted and at 4:38 p. m. rain began.

Figure 3 gives the march of direction and velocity from 3:00 p. m. to 4:15 p. m. from the six observations. After 3:00 p. m. the wind turned slowly clockwise in the lower 600 meters until time of wind shift when it turned rapidly clockwise. The velocity continued to decrease in the first 600 meters and increased slowly above. Between 3:30 and 4:00 p. m. the decrease in velocity was marked and extended upward to 1,000 meters elevation, although occurring later at higher levels.

The northwest wind was most pronounced at an elevation of about 400 meters. At 1,000 meters there was little evidence of the changes taking place in lower levels. A study of these figures makes it obvious that the northwest wind flowed in over the surface and was strongest near the surface. The frictional drag probably accounts for the lighter wind at 200 meters than at 400 meters elevation, at the time of the wind shift.

This thunderstorm passed northwest of the station. At the Langley Field Meteorological Station, 9,000 meters north-northwest of the Fort Monroe Meteorological Station, the wind shifted at 3:30 p. m. and rain began at 4:20 p. m.

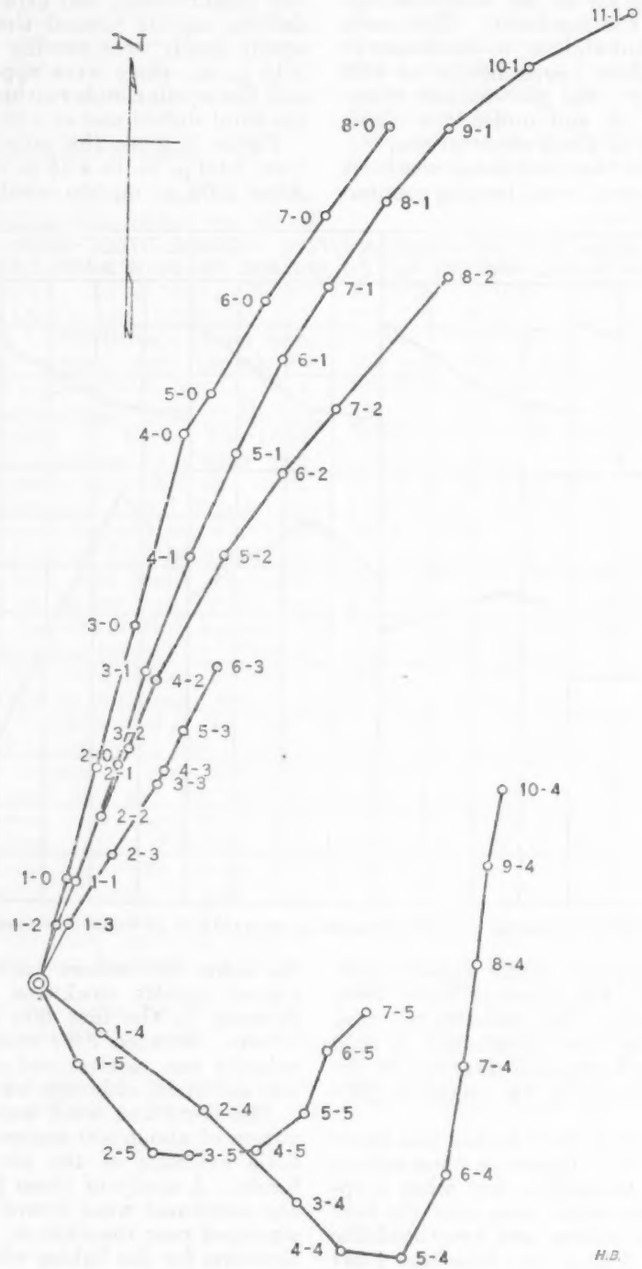


FIG. 2.—Horizontal projections of balloon paths.

[To face p. 727.]

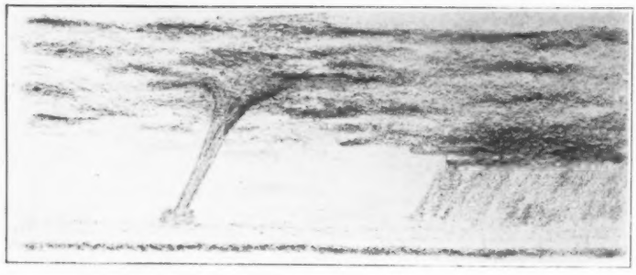


FIG. 1.—Waterspout when first observed at 1:15 p. m.

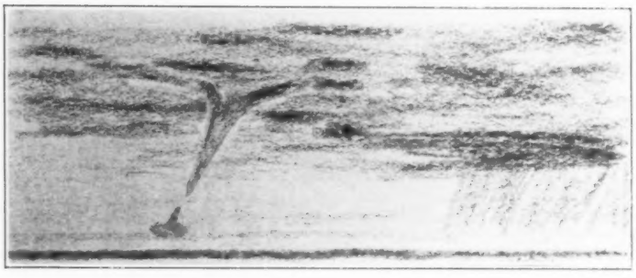


FIG. 2.—Appearance after spout became severed.

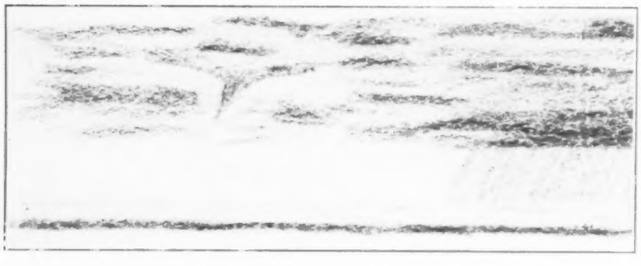


FIG. 3.—Waterspout just before disappearance.

These observations seem to indicate that the lull before the storm extends to heights of 800 to 1,000 meters and that the squall flows in over the surface. The clockwise turning of the wind during the passage of the storm is what would be expected from a counterclockwise whirl with its southeast quadrant passing northeastward over the observer. It was impossible, on account of clouds, to get observations to heights exceeding 1,000 meters during this period.

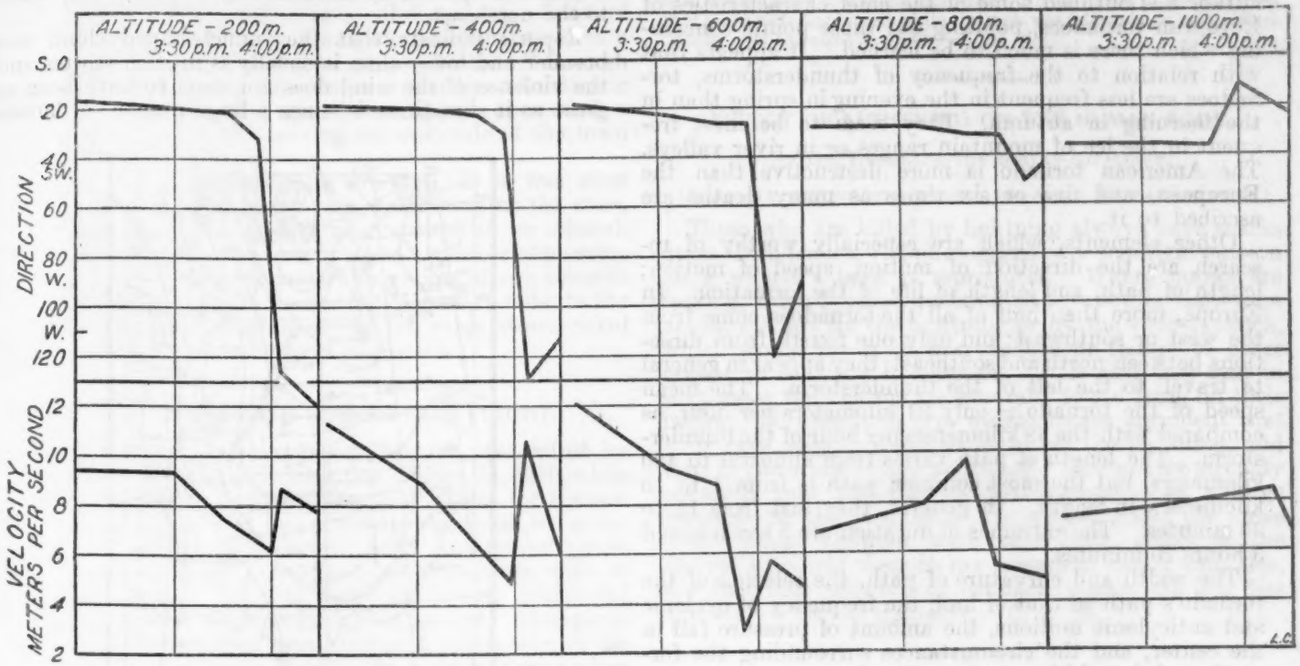


FIG. 3.—March of direction and velocity from 3:00 p. m. to 4:15 p. m. from the six observations.

WATERSPOUT OBSERVED AT SAN JUAN, PORTO RICO, SEPTEMBER 10, 1919.

By WILLIAM C. HAINES, Observer.

[Dated Weather Bureau, San Juan, P. R., Oct. 27, 1919.]

An exceptionally well-defined and magnificent waterspout was observed at San Juan, P. R., by a number of people on the evening of September 10. It occurred in connection with a thunderstorm which formed in the late afternoon to the north and northeast of the city and hung almost stationary until late in the evening.

When the waterspout was first observed at 4.45 p. m. by the writer, who was located at the Weather Bureau station approximately 1 mile east of the city, the funnel-shaped cloud extended from a dark mass of storm cloud on the outer edge of the thunderstorm proper to the surface of the ocean where a swirl of spray was plainly visible. The funnel-like cloud was nearly straight, although it was inclined from the vertical at an angle of from 25 to 30 degrees, the bottom portion extending toward the southwest away from the vicinity of the thunderstorm. (See Fig. 1.) The funnel increased very gradually in diameter from the cloud spray at the surface of the water until just before it entered the base cloud where it rapidly increased in size. The spout remained practically motionless until about 5:00 p. m. when it began to show evidences of dissolving about one-fourth the distance up the column; within a period of five minutes it had become entirely severed, the bottom portion and spray remaining visible for several seconds. (See Fig. 2.) The upper portion of the column gradually shortened and by 5.15 p. m. it had entirely emerged into the general base cloud. (See Fig. 3.) The waterspout formed to the northwest of the station at a distance estimated to be from 5 to 8 miles.

Several peals of thunder were heard between 5:00 p. m. and 5.15 p. m. Rain could be seen falling a short distance to the north, although none actually fell at the station. The clouds in the region of the thunderstorm were apparently from the northeast, while the cumulus and strato-cumulus clouds overhead and in other portions of the sky were from the southwest. The upper clouds during the day had been from the northwest, although none were visible at the time of occurrence of the waterspout. The wind was moderate and from the east during the afternoon until about 4:00 p. m. when it became light and shifted to the southwest and west and so continued during the prevalence of the thunderstorm.

A sharp lookout was kept during the evening but no other spout was observed. Unfortunately no photographs were taken of this waterspout by anybody as far as could be learned.

TWO WATERSPOUTS OBSERVED AT RABAT, MOROCCO, ON DECEMBER 18, 1917.

By J. PEYRIGUEY.[1]

[Reprinted fro Science Abstracts, July, 1918, pp. 287-288.]

Descriptions are given of two waterspouts associated with heavy cumulo-nimbus cloud, which came up from the Atlantic with a strong southwest wind. Both were at least about 350 meters long, and extended from the cloud to 50 meters above the surface. The first waterspout was about 4 meters in diameter, the second only about 1 meter. Subsequently a heavy thunderstorm was experienced.—*R. C.*

[1] Comptes Rendus, 166, Jan. 7, 1918, pp. 48-49.

SOME CHARACTERISTICS OF TORNADOES.

By ALFRED WEGENER.[1]

[Abstracted from *Meteorologische Zeitschrift*, Sept.-Oct., 1918, pp. 245-249.]

For the benefit of those interested in tornadoes, the author has outlined some of the chief characteristics of European tornadoes, pointing out those points concerning which there is much to be learned. It appears that with relation to the frequency of thunderstorms, tornadoes are less frequent in the evening in spring than in the morning in autumn. They seem to be most frequent in the lee of mountain ranges or in river valleys. The American tornado is more destructive than the European, and five or six times as many deaths are ascribed to it.

Other elements, which are especially worthy of research are the direction of motion, speed of motion; length of path, and length of life of the formation. In Europe, more than half of all the tornadoes come from the west or southwest; and only one fourth from directions between north and southeast; they appear in general to travel to the left of the thunderstorm. The mean speed of the tornado is only 23 kilometers per hour, as compared with the 38 kilometers per hour of the thunderstorm. The length of path varies from almost 0 to 400 kilometers, but the most common path is from 1 to 10 kilometers, in length. In general, they last from 12 to 30 minutes. The extremes of duration are 5 seconds and 3 hours 20 minutes.

The width and curvature of path, the relation of the tornado's path to that of hail, the frequency of cyclonic and anticylonic motions, the amount of pressure fall in the center, and the circumstances surrounding the formation of the whirl, are also pointed out as points upon which much information is needed. Photographic methods are recommended, whenever feasible, on account of the rapid motion and excitement attending the passing of such a formation.—*C. L. M.*

[1] Author of "Wind und Wasserhosen in Europa," Braunschweig, 1917.

TORNADOES OF OCTOBER 8, 1919.

At 4:04 p. m. of October 8 a tornado struck Hoisington, a town of 2,000 population in Barton County, Kansas, and devastated a strip 400 feet wide through the business and main residence section, either partially or completely wrecking between 50 and 60 houses, and causing a total damage estimated at $200,000. Twenty five persons were injured, three killed outright, and one died later from injuries incurred.

The storm formed three miles southwest of Hoisington. An eye witness, Mr. John Gruber, who was operating a thrashing rig two and a half miles southwest of Hoisington, stated that clouds from every direction started drifting toward a point half a mile to the southwest of him. The closer they came to this point the faster they moved until within only a few seconds they seemed to be racing with incredible speed. There was no whirling or circular motion until they had come together. After this occurred a terrible roar was heard, similar to that of a heavy freight train, and the whirl seemed to hover over the same spot for several seconds before the funnel shaped cloud lengthened sufficiently to reach the ground, when it headed toward the northeast, striking first the railroad Young Men's Christian Association Building at Hoisington and the Van Noy Hotel, and then tearing a path directly to the northeast through the town. The force of the storm was apparently spent 5 or 6 miles northeast of Hoisington, though a cancelled check and other papers of Hoisington business houses were picked up the next day at Lincoln, 55 miles to the northeast.

Reports indicate that the funnel-shaped cloud was broader and lower than it usually is in such storms and the violence of the wind does not seem to have been as great as it sometimes is, since a large number of houses

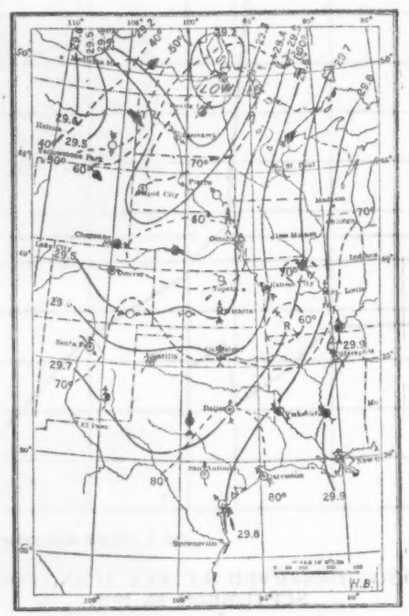


FIG. 1.—Tornadoes of Oct. 8.

directly in the storm path were merely injured by having the roof blown off or a side blown out instead of being completely destroyed.

The storm struck the town without warning, except for the heavy fall of rain and hail that preceded it. A few minutes after it passed the sky cleared and the sun was shining brightly.

Half an hour after the first storm a second tornado formed about 18 miles southwest of Hoisington, near the town of Dundee, and moved toward the northwest for 8 miles, disappearing 2 miles northwest of Great Bend. Several farm houses and buildings were wrecked, live stock were killed, and a fine orchard was ruined, but no one was injured and the total damage was comparatively small.—*S. D. F.* (from press reports).

NOTE.—Fig. 1, the weather map for 7 p. m., 90th meridian time, shows no temperature conditions at the surface which would indicate tornado weather. There must have been converging winds or a cold over-running wind aloft.—C. F. B.

BALL LIGHTNING AT SALINA, KANS.

At about 6.30 p. m., October 8, 1919, a brilliant display of ball lightning occurred at Salina, Kans., on one of the most frequented street intersections of the town. Eyewitnesses described it as "a ball of fire as large as a washtub floating low in the air." It struck the north-

west corner of the Campbell Building, corner Santa Fe and Iron Avenue, about midway to the top of the building, which is 35 feet high, tore out some brick, demolished a second-story window, and then exploded with a bang that resembled the noise made by the discharge of a large pistol, filling the air with balls of fire as large as baseballs, which floated away in all directions. Some of these balls followed trolley and electric-light wires in a snaky sort of manner and some simply floated off through the air independently of any objects near by. An electric switch box across the street was ripped open and a transformer destroyed, leaving the east side of the town in darkness.

The street was practically deserted, as it was after closing hours and a heavy rain was falling at the time, and fortunately no one was near enough to be injured, though the display was seen by quite a number of persons.

This occurred approximately two hours after a tornado had struck the town of Hoisington, Kans., 70 miles to the southwest, and was probably in the same storm cloud from which the tornado cloud originated.

LIGHTNING DEATH DURING KITE FLIGHT.

Mr. Charles H. Heckelsmiller, laborer, was killed by lightning at Ellendale, N. Dak., on August 28, 1919, while assisting in a kite flight. Immediate efforts for resuscitation were made and two physicians were on the scene within 15 minutes. A severe burn was found across Mr. Heckelsmiller's chest and on the inner side of his right wrist. The kite flight was nearly completed and three of the six kites had been landed. It appears that Mr. Heckelsmiller was holding a splice wire in his hand and was standing close to the main kite wire when the flash occurred. At the time of the flash two employees were in the reel house and they state that the house was filled with flame. A line of sparks resembling a huge skyrocket was seen to follow up the wire [1] and these set the grass beneath on fire, as the ground was very dry, no rain having fallen for nearly two weeks. About 1,750 meters of wire were out at the time, and it was completely fused in the air. This is the first accident of its kind that has occurred to an employee of the Weather Bureau during the period of about 25 years, in which the Weather Bureau has engaged in kite observation work.—*Weather Bureau Topics and Personnel*, August, 1919.

DEATH BY LIGHTNING.

[Abstracted from note in Symons's Met'l. Mag., October, 1919, vol. 54, p. 104.]

Dr. A. G. Newell describes an interesting phenomenon in connection with the burns received by a man who was killed by a lightning stroke in London. The man and his wife were walking in the open, near a row of elm trees, when he was struck. The wife was momentarily stunned, but upon recovering she saw her husband standing erect with a blazing line up and down the back of his coat. He died immediately, and fell backward against an iron fence. Severe burns on his back indicated that he was struck from the right side of his back. From the right shoulder and across the chest and down to the lower of the front of the abdomen impressions of branches and leaves were clearly imprinted on the skin, showing like an X-ray plate how certain rays of light were impeded by the branches and foliage, whilst others made the contours of these. There were two distinct branches with leaves, one occupying the space between the right iliac crest to near the ensiform cartilage and the other proceeding down on the left side from the stomach to the left iliac crest. To my mind it would appear as if these were implanted while the man was falling back with a flash coming over the right shoulder.—*C. L. M.*

[1] I observed a similar line of white-hot beads when about 1,600 meters of wire was fused by lightning during a kite flight at Blue Hill Observatory, Mar. 6, 1913. The thunder was an *even* peal, since the lightning producing it had followed the smooth curve of the wire.—*C. F. Brooks.*

EFFECT OF LIGHTNING ON THE HUMAN BODY.

By DR. LADISLAUS VON SZALAY-UJFALUSSY.

[Abstracted from *Meteorologische Zeitschrift*, July–August, 1918, vol. 35, pp. 192–194.]

Those who are killed by lightning always have marks upon their bodies. A photograph of a dendritic pattern on a woman's back is reproduced. Where marks are lacking, there is some question as to whether they were actually killed by the lightning or by the sudden shock, which would result in heart failure or failure of other organs to continue to function. It is also true that in such cases the victims are generally found lying on their backs. This tends to give weight to the argument that their eyes were directed so as to see the lightning, and thus to cause the falling backward. The author strongly contends that the psychological element has a large influence on the fatality of the stroke, citing the cases where small children were uninjured, although the mother who held them in her arms was killed; and, also, the fact that sleeping or drunken people are less frequently victims of lightning.—*C. L. M.*

EFFECT OF LIGHTNING ON CONCRETE BRIDGE.

The *Engineering News-Record* of July 10, 1919 (pp. 68–69), tells of the effect produced upon a concrete bridge at Iowa City, Iowa, by a stroke of lightning on June 9, 1919. The bridge had a sidewalk between the roadway and a handrail, which was supported by half-inch steel rods, both laterally and longitudinally. The force of the lightning apparently acted between the handrail and the sidewalk, with the result that the handrail was displaced toward the north and the sidewalk toward the south, the rupture being 96 feet in length. One of the curious features noted was the pulling apart of the steel rods, and then freeing them from the concrete medium in which they were held while the pulling took place. This is shown by the fact that parts of the steel rods found in the conduit beneath the sidewalk were absolutely free from concrete, except for a very thin skin coat.—*C. L. M*

LIGHTNING HOLES.

On the shore of Lake Congamond, Southwick, Mass., in July, 1917, Mr. R. Marsh states that lightining struck on the water's edge, making a hole about a foot in diameter, then went under ground 6 feet, and came out in another hole about the same size, throwing ashes to the tree-tops. Other branches of the lightning hole came to the surface in smaller openings.—*C. F. B.*

THE RELATION OF WIND DIRECTION TO SUBSEQUENT PRECIPITATION IN CENTRAL OHIO.

By HOWARD H. MARTIN, Observer.

(Dated Weather Bureau, Columbus, Ohio, Nov. 22, 1919.)

SYNOPSIS.

It is the primary purpose of this paper to show, by means of table and graph, the true existing relation between the observed wind direction and subsequent precipitation. To do this, it is first necessary to establish and consider the probable frequency of precipitation in the district that the apparent relations between the two phenomena may be reduced to the true relations. Hence, the paper is divided into two parts, the first treating the frequency factor, and the second dealing with the relation of the prevailing wind direction to subsequent precipitation, and the application of the frequency factor to determine the true prognostic value of the wind direction.

INTRODUCTION.

PART I. In the rich agricultural regions of central Ohio, rain falls with a frequency probably greater than over many adjacent districts, 3.2 days being the average interval between showers, this interval, of course, varying greatly with the seasons and being considerably less during those periods when rain is most to be expected and slightly greater during the months of minimum frequency.

TABLE 1.—*Frequency of rainy days and of dry and wet spells of variable length, in central Ohio, 1909–1918, inclusive.*

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	For 10 years.
Number of days considered.	310	282	310	300	310	300	310	310	300	310	300	310	3,652
Number of days with 0.01 inch or more precipitation.	164	117	130	146	134	113	120	113	94	106	94	146	1,477
WET PERIODS.													
Consecutive days with 0.01 inch or more rainfall per day:													
2 days	12	17	15	15	19	10	24	14	17	20	18	22	203
3 days	14	6	10	10	10	5	6	8	8	5	2	9	93
4 days	11	4	4	6	5	5	2	4	2	1	4	2	50
5 days or more	2	1	1	2	0	0	0	1	0	3	1	3	14
DRY PERIODS.													
Consecutive days without measurable rainfall on any day:													
2 days	14	15	16	20	13	19	21	17	10	18	7	16	186
3 days	11	17	11	13	11	14	11	9	5	7	8	7	124
4 days	6	9	8	6	7	9	5	4	5	6	6	11	82
5 days	6	4	2	4	3	3	3	4	7	5	4	6	51
6 days	1	3	2	1	1	3	2	4	6	2	4	2	31
7 days or more	1	2	6	2	7	5	8	10	5	9	9	3	67

Table 1 shows the actual frequency of rainy days and of wet and dry spells in central Ohio, during the period under investigation, 1909–1918, inclusive. From these data may be deduced the rainfall probability [1] and other important facts related to the occurrence of precipitation. However, to determine this frequency in a form applicable to meteorological relations, it is essential that the probable frequency with which rain will occur within 12, 24, or 48 hours after a given instant be computed. To do this, the formula—

Probability of rainfall within—

$$12 \text{ hours} = [R + 12\ (\tfrac{1}{2}\ (A) + B + C + D + E)]/T.$$
$$24 \text{ hours} = [R + 24\ (\tfrac{1}{2}\ (A + B) + C + D + E)]/T.$$
$$36 \text{ hours} = [R + 36\ (\tfrac{1}{2}\ (A + B + C) + D + E)]/T.$$
$$48 \text{ hours} = [R + 48\ (\tfrac{1}{2}\ (A + B + C + D) + E)]/T.$$

[1] For method of determining values of probability, see Hann's Climatology, Eng. ed., p. 61–62; Hellman's "Niederschlage in den Norddeutschen Stromgebieten," vol. 1, p. 179 ffg.

is employed. Here (R) is the time in hours during which rain has fallen; (A), (B), (C), (D), and (E) the numbers of dry periods according to length, 0 to 12 hours, 12 to 24 hours, 24 to 36 hours, 36 to 48 hours and in excess of 48 hours, respectively; and (T) the whole time, in hours, in the period studied. A full discussion of this formula is to be found in an earlier number of the REVIEW.[2]

TABLE 2.—*Showing the probable frequency of precipitation in central Ohio, based upon the rainfall records of Columbus, 1909–1918, inclusive.*

At any instant, probability of rainfall occurring within—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.
12 hours	39	29	21	23	20	21	18	13	12	25	31	30
24 hours	56	48	38	41	35	38	35	28	20	31	37	48
36 hours	74	61	51	54	45	50	42	38	32	35	47	59
48 hours	88	68	56	63	56	59	44	47	39	45	57	66

Table 2 sets forth the results of computation from this formula, showing the probability of rain within the given periods subsequent to any instant.

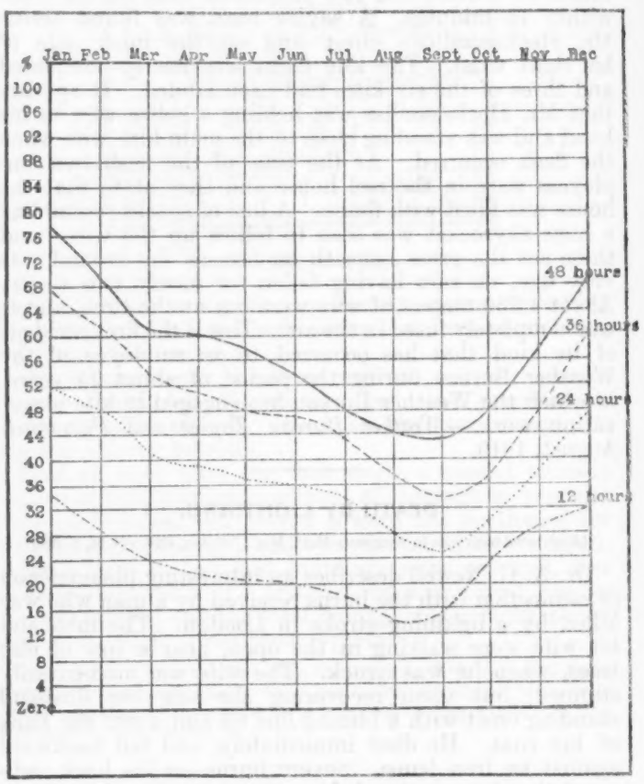


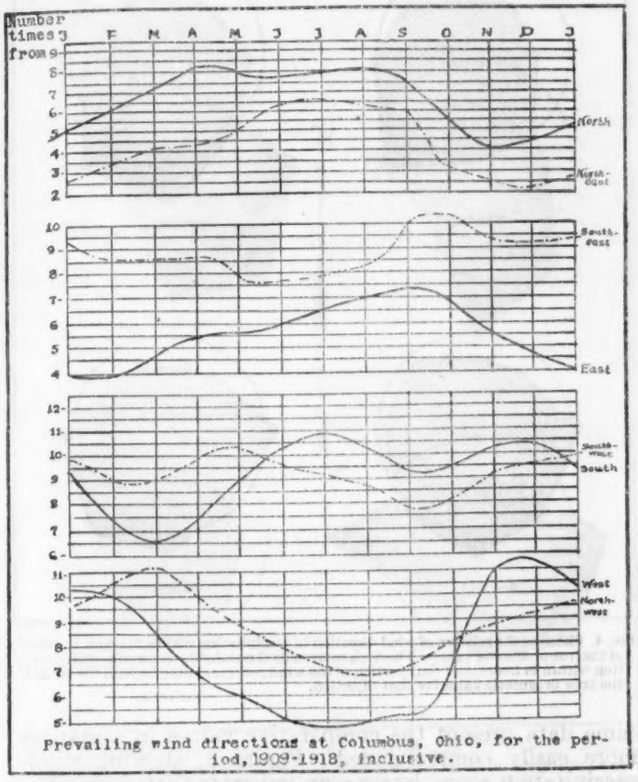
FIG. 1.—Showing the probability of precipitation occurring within 12, 24, 36, and 48 hours after any given instant, based on the records of rainfall at Columbus, Ohio, for the period 1909–1918, inclusive.

Fig. 1 presents graphically the same data. The curves have, however, been smoothed by means of the formula, January = (Dec. + 2 Jan. + Feb.)/4, and show that January is the month of greatest rainfall probability while August and September are the months of least. The

[2] Fog in Central Ohio and its Relation to Subsequent Weather Changes, Howard H. Martin M., W. R., July, 1919, 47: 471–472. See discussion by Dr. C. F. Brooks.

rapid decrease in probability from January to March and the rapid increase in the same value from September to December are especially to be noted. It is further shown that the probability of rain occurring within 24 or 48 hours after a given instant is generally high throughout the year, sufficiently so to render it difficult indeed to establish true prognostic values for many studied phenomena, but unless this factor is given proper consideration, the apparent relations are by no means the true relations.

PART II. That a positive relation exists between certain wind directions and subsequent precipitation is



Prevailing wind directions at Columbus, Ohio, for the period, 1909-1918, inclusive.

FIG. 2.—Based on twice-daily observations of wind direction, 7 a. m. and 7 p. m.

unquestioned, and a close study of this relation in central Ohio reveals some very interesting points. Each direction has, of course, its month or period of maximum frequency, which fig. 2 brings out very forcibly. For instance, it is to be noted that the north wind prevails more often from April to August than from November to February and that the west wind is more frequent from November to February than during any other part of the year, while the northwest wind attains its maximum frequency in March and its minimum in August. The constancy of the southwest wind is also to be observed, as well as that of the southeast wind, both directions being noted frequently throughout the year.

TABLE 3.—*Showing the number of times the wind was observed from the various directions at Columbus, Ohio, during the period 1909–1918, inclusive. Based on the twice daily observations, 7 a. m. and 7 p. m.*

Number of times wind was observed from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
North	50	61	66	96	73	79	80	76	91	50	33	45	800
Northeast	22	32	48	35	48	70	64	65	64	47	18	24	537
East	37	35	48	56	55	60	66	68	78	70	52	51	676
Southeast	97	82	85	94	74	75	85	69	107	117	77	96	1,058
South	100	67	63	73	90	102	112	106	87	92	108	105	1,105
Southwest	111	77	93	96	111	93	91	96	69	78	98	92	1,105
West	93	110	87	57	70	47	43	60	37	73	131	115	923
Northwest	97	100	129	90	98	71	75	67	65	90	83	92	1,057
All directions	607	564	619	597	619	597	616	607	598	617	600	620	7,261
Calms	13	0	1	5	1	3	4	13	2	3	0	0	43

Since the curves in fig. 2 were smoothed by means of the simple formula given in Part I, a glance at Table 3 will show the actual number of times the wind was observed from the various directions at Columbus during the period, 1909–1918, inclusive. While the wind prevails from the southwest throughout practically the entire year, the variations shown by the twice daily observations are unique. It is shown that westerly winds prevail from November to March and southerly winds during the remaining months of the year.

TABLE 4.—*Showing the number of times the observed wind direction was followed by precipitation within 12, 24, and 48 hours. Observations at Columbus, Ohio, 1909–1918, inclusive.*

RAIN WITHIN 12 HOURS.

Wind blowing from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
North	11	11	9	10	4	3	2	7	6	6	1	6	76
Northeast	12	10	3	4	3	3	3	12	3	6	3	3	65
East	6	4	5	4	3	10	4	3	3	4	15	10	71
Southeast	32	35	21	27	45	20	22	6	12	6	5	35	266
South	26	16	10	16	10	15	26	6	20	10	16	26	197
Southwest	36	22	6	34	10	10	22	4	10	21	6	16	197
West	26	17	10	10	16	10	15	8	4	16	12	8	152
Northwest	32	12	6	6	10	6	4	7	4	6	6	15	114

RAIN WITHIN 24 HOURS.

North	25	18	16	26	13	11	7	13	7	12	3	8	159
Northeast	18	13	7	7	10	13	9	18	9	9	7	6	126
East	17	9	20	9	19	31	31	14	13	14	27	44	248
Southeast	57	71	36	59	62	56	44	22	39	26	31	65	568
South	61	42	42	46	60	34	66	42	54	46	38	44	575
Southwest	48	39	16	50	42	36	45	10	36	27	21	46	416
West	42	23	15	16	37	26	20	18	15	34	32	42	320
Northwest	38	28	17	12	26	18	10	9	8	12	12	31	219

RAIN WITHIN 48 HOURS.

North	33	25	24	38	21	20	22	21	18	20	6	9	257
Northeast	20	16	10	10	26	16	21	27	18	15	10	16	205
East	33	30	24	21	30	37	61	35	25	25	33	44	398
Southeast	68	84	40	78	70	72	70	33	60	52	36	85	748
South	86	72	60	70	88	58	76	58	63	57	60	74	822
Southwest	58	60	24	65	50	45	55	18	51	35	33	60	554
West	53	48	24	32	68	50	45	24	18	44	58	78	542
Northwest	58	48	58	38	47	28	22	20	14	28	34	58	453

A careful consideration of Table 4 will reveal the fact that the southeast wind is, in central Ohio, typically a rain wind, with the south wind of slightly less importance.

TABLE 5.—*Showing the apparent prognostic values of wind directions, by months, in terms of percentage of possible, Columbus, Ohio, 1909–1918, inclusive.*

RAIN WITHIN 12 HOURS.

Wind blowing from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.
North	22	18	14	10	6	4	3	10	7	12	3	14	10
Northeast	54	33	6	11	6	4	5	19	5	13	15	12	15
East	15	10	11	8	5	17	6	4	4	4	25	25	11
Southeast	36	39	24	30	56	25	27	8	12	6	5	38	25
South	26	20	14	23	11	15	24	6	22	11	16	26	18
Southwest	33	27	7	34	9	11	25	4	14	26	6	18	18
West	28	17	11	17	23	20	30	16	8	21	11	7	17
Northwest	32	12	5	7	10	9	5	10	7	6	8	17	11

RAIN WITHIN 24 HOURS.

North	50	30	24	27	18	14	9	18	8	24	10	18	21
Northeast	77	39	14	20	21	10	14	27	14	19	38	25	27
East	42	22	41	16	30	51	47	20	18	20	48	88	37
Southeast	62	78	40	65	77	70	55	27	39	26	33	72	54
South	61	64	60	66	66	34	60	42	60	52	38	44	53
Southwest	44	50	18	50	39	40	50	10	51	34	21	51	38
West	45	23	13	27	53	50	40	36	30	42	29	38	36
Northwest	38	28	13	13	26	26	12	13	13	13	15	35	20

RAIN WITHIN 48 HOURS.

North	66	41	37	40	28	28	27	27	20	40	21	20	33
Northeast	87	47	21	31	54	23	33	42	28	30	55	65	43
East	82	76	51	40	48	62	96	50	34	36	51	88	59
Southeast	76	98	44	87	87	90	87	41	60	52	40	95	70
South	86	96	88	90	98	58	60	58	70	63	60	74	76
Southwest	55	75	27	65	48	50	61	18	72	44	33	66	52
West	60	48	28	53	97	98	92	44	36	55	53	70	64
Northwest	58	48	45	44	47	40	27	28	23	31	42	65	11

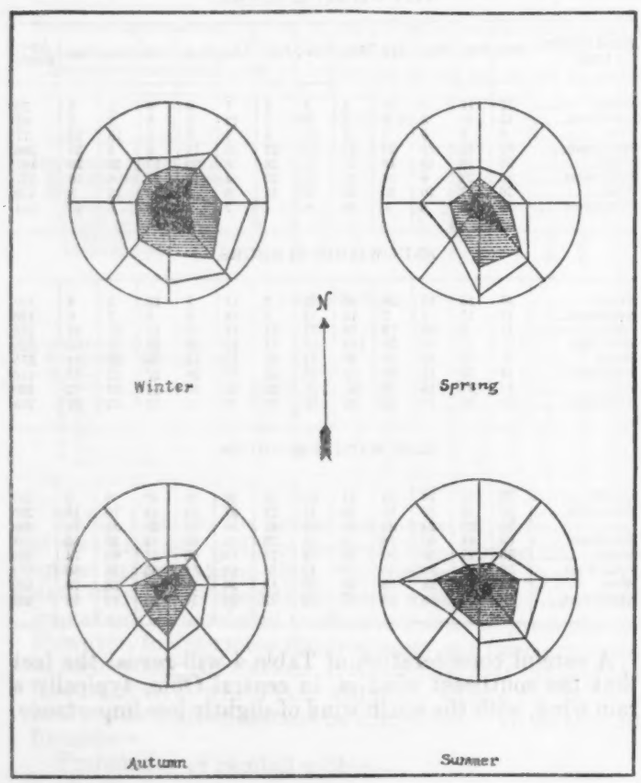


FIG. 3.—Wind roses for Columbus, Ohio, based on 10 years' record, 1909–1918, inclusive, showing the *apparent* relation between wind direction and subsequent precipitation. Solid area indicates 12-hour values; shaded, and open, 48-hour.

Since the actual number of times that precipitation follows an observed wind direction is not, in itself, indicative of the forecast value of that direction, the apparent percentage of prognostic value for each direction has been determined by dividing the total number of times rain has followed a given direction within 12, 24, and 48 hours by the total number of times the wind has been observed from that direction. The results of this computation are shown in Table 5. Wind roses from the same data present the comparative values in a manner more easily comprehended. Figure 3, showing wind-precipitation roses, by seasons, indicates that during the winter months, December to February, inclusive, the rain winds for central Ohio are from the east and southeast to south; that for the spring months, March to May, inclusive, from the southeast and south, with a slight increase in the prognostic value of the west wind; that for the summer, June to August, inclusive, the west wind increases rapidly in prognostic value, and is the rain wind for the season, with east and southeast of secondary importance; and that for autumnal months, September to November, inclusive, the south wind shows the highest value, with the west wind rapidly decreasing in importance as a rainy wind. The west wind is, during the summer months, favorable to the building up of cumuli, which in turn, develop into thunderstorms, hence its importance as a rain-forecast factor during that season. Reference to Table 4 will show that 98 per cent of the observed west winds during the month of June are followed by precipitation within 48 hours, while May and June both show values well above 90 per cent.

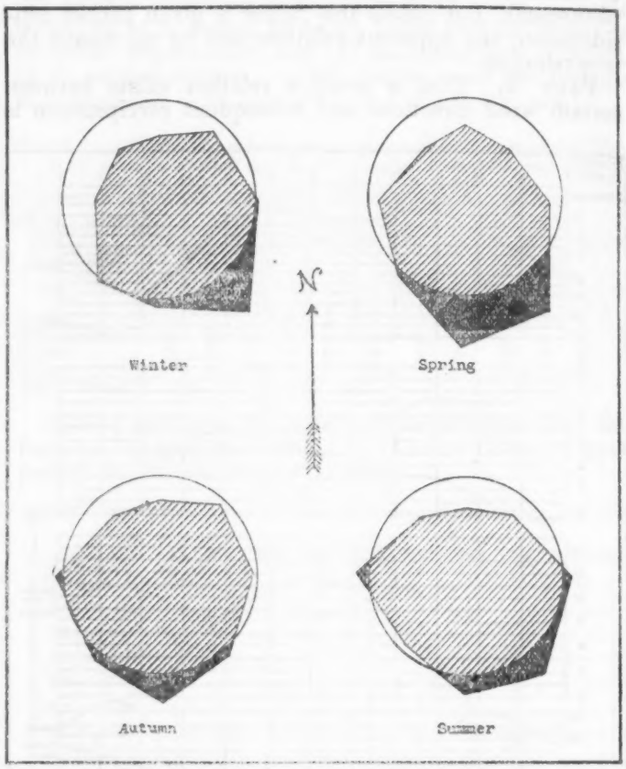


FIG. 4. Showing the relation of wind direction to precipitation within 24 hours, in terms of the true prognostic values. The circle represents the probable occurrence of precipitation within 24 hours, and that portion of the wind rose extending beyond the circle is the true prognostic value for that direction.

The apparent relations of wind direction to the occurrence of subsequent precipitation shown by fig. 3 can not be considered as scientifically accurate, since no

consideration has been given the probability of the occurrence of precipitation, regardless of wind direction. These percentages of probability have been computed for central Ohio and by applying the formula

$$\frac{P-p}{100-p}=V$$

where P is the *apparent* percentage of verification, p the percentage possible by chance, as determined in previous tables, and V the true prognostic value, the

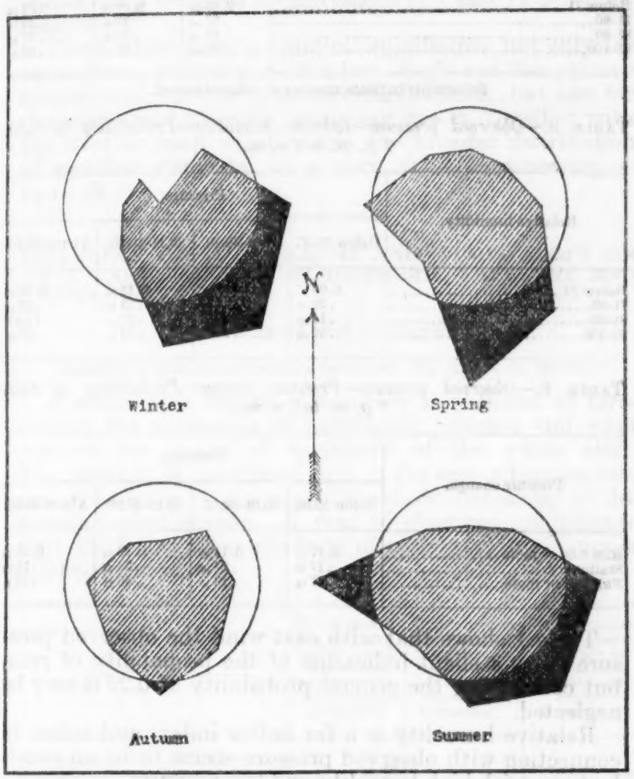


FIG. 5.—Showing the relation of wind direction to precipitation within 48 hours in terms of the true prognostic values. The circle represents the probable occurrence of precipitation within 48 hours, and that portion of the wind rose extending beyond the circle is the true prognostic value for that direction.

apparent relation may be shown reduced to the true prognostic values. This has been done, and is shown graphically in fig. 4, as applicable to the 24-hour relation. In the case of this graph, the circle defines the probability of precipitation possible by chance, the wind-rose showing the true prognostic values of the several directions, only that portion extending beyond the circle, however, representing a positive relation. Thus, it will be readily observed that in the winter, southeast winds are of greatest importance as harbingers of rain, while in the spring, the south wind is of predominating value. The relation between wind and precipitation during the summer and autumn is relatively small, and the west wind appears of increased value.

A glance at fig. 5 will reveal startling differences in the 24- and 48-hour prognostic values. Here, as in fig. 4, the southeast wind appears of greatest prognostic value during the winter months but the east and south winds are also of importance. During the spring, it is to be noted that the south wind continues predominant, and has increased in value appreciably. During the spring also the west wind shows the first positive relation to subsequent rainfall. And during the summer months, it has attained the position of being the rainy wind of the season, showing a high positive value. The winds east to south have also increased in value and may be considered favorable indications of coming showers. In the autumn, there is indicated but a slight relation of the south wind to approaching rain, all other directions being of no importance whatever.

The value of establishing this relation between the several wind directions and approaching weather changes is apparent. Quite frequently indications point to showers, yet with the wind in a dry quarter, the presence of clouds and even of falling barometer can not always be considered faithful prognostics. It may be stated here that the writer has determined further that the south wind, observed at night during the autumn months, was followed 94 per cent of the times observed by precipitation before the following night, but that the observation of this wind in the morning was followed by rain within 24 hours only upon 10 per cent of the times noted. It was also determined that the southeast wind observed at night was the most favorable rain indication during both the winter and spring months, but that the west wind at night during the summer was followed by rain within 24 hours 88 per cent of the times observed and within 48 hours 97 per cent of such times. Further, it is believed that the relation of the wind at sunset or shortly thereafter is, in central Ohio at least, of greatest value to subsequent rainfall, and that in the morning is of secondary importance. In other words, the presence of a wind from a direction shown in figs. 4 or 5 to be a rain-wind will, if observed at sunset, be followed by precipitation with a far greater degree of certainty than the same wind direction observed in the morning. Many times the southeast wind at night precedes a cloudy morning, with the wind in the south or southwest, and with precipitation following within a few hours, but rarely does the southeast wind of the morning precede rain by less than 24 hours.

The writer believes that the direction of the surface wind, if studied carefully, will reveal many peculiarities in itself, which, in turn, will be of the greatest value to local forecasting. As before stated, there can exist no doubt but that a positive relation exists between certain surface wind directions and subsequent rainfall, and with the data at hand, study can but prove of incalculable value in the determination of this relation.

PROBABILITY OF RAIN IN SUMMER AT ATLANTA, GA.

By W. W. REED, Assist. Observer.

[Dated: Weather Bureau, Atlanta, Ga., Oct. 23, 1919.]

In a paper on the probability of rain in summer, Bruno Rolf [1] has advanced a method of forecasting from local conditions, whose application to the conditions observed at Stockholm meets with success in 68 per cent of the predictions.

Observed pressure is taken as the chief argument and by combination with other elements such as relative humidity, cloudiness, and wind direction he has derived curves of probability of rain, which he designates barombrometric curves or barombrograms.

The method of derivation in his work is largely mathematical and can not be entered into here, but it may be interesting to give some tables somewhat similar to his showing the probability of rain at Atlanta, using as arguments wind direction, pressure, pressure change, and relative humidity.

In this investigation the wind direction is taken as the chief argument, since it is believed to be one of the most important at any season and because of the slight variations in pressure in summer probably the most important factor in this region. For the first test the east wind was chosen. The a. m. observation is made the basis of the forecast, and the 12-hour period beginning at 7 p. m. is taken as the period for verification.

Probability of rain in summer at Atlanta, Ga., based on records from June to August, 1890–1919.

EAST WIND.

Wind observed from the east (7 a. m.)	times..	415
Rainfall 0.01 inch or more, 7 p. m. to 7 a. m.	times..	90
Probability of rain		0.22

TABLE 1.—*Pressure.*

Observed pressure.	Number of times.	Probability of rain.
Below 30.01	63	0.24
30.01–30.10	160	.22
30.11–30.20	145	.21
Above 30.20	47	.19

TABLE 2.—*Relative humidity.*

Percentage.	Number of times.	Probability of rain.
Below 71	71	0.10
71–80	89	.18
81–90	123	.20
91–100	132	.33

TABLE 3.—*Pressure change.*

Change.	Number of times.	Probability of rain.
Rise 0.10 or more	62	0.16
Rise 0.08 or 0.09	38	.13
Rise 0.06 or 0.07	39	.20
Stationary	234	.23
Fall 0.06 or 0.07	19	.26
Fall 0.08 or 0.09	12	.25
Fall 0.10 or more	11	.54

[1] Probabilité et prognostics des pluies d'été, Upsala, 1917, vii, 25, [2] p., charts, tables. A translation has been prepared and placed in the Weather Bureau Library.

TABLE 4.—*Pressure change—Relative humidity—Probability of rain 7 p. m. to 7 a. m.*

Relative humidity.	Pressure rise 0.06 or more.	Pressure stationary.	Pressure fall 0.06 or more.
Below 71	0.03_{29}	0.09_{23}	0.30_{10}
71–80	$.07_{28}$	$.20_{40}$	$.33_{12}$
81–90	$.15_{46}$	$.20_{72}$	$.36_{11}$
91–100	$.33_{42}$	$.32_{31}$	$.33_{9}$

Subscripts indicate number of times observed.

TABLE 5.—*Observed pressure—Relative humidity—Probability of rain 7 p. m. to 7 a. m.*

Relative humidity.	Pressure.			
	Below 30.00.	30.01–30.10.	30.11–30.20.	Above 30.20.
Below 71	0.00_{6}	0.10_{31}	0.18_{22}	0.00_{12}
71–80	$.29_{17}$	$.25_{28}$	$.13_{31}$	$.00_{13}$
81–90	$.14_{22}$	$.22_{54}$	$.15_{41}$	$(.50)_{2}$
91–100	$.39_{18}$	$.28_{47}$	$.33_{51}$	$.38_{16}$

TABLE 6.—*Observed pressure—Pressure change—Probability of rain 7 p. m. to 7 a. m.*

Pressure change.	Pressure.			
	Below 30.00.	30.01–30.10.	30.11–30.20.	Above 30.20.
Rise 0.06 or more	0.17_{12}	0.14_{49}	0.12_{56}	0.25_{28}
Stationary	$.17_{36}$	$.27_{109}$	$.23_{77}$	$.11_{18}$
Fall 0.06 or more	$.47_{15}$	$.13_{15}$	$.46_{11}$	$.00_{1}$

Table 1 shows that with east wind the observed pressure gives a slight indication of the probability of rain, but considering the general probability of 0.22 it may be neglected.

Relative humidity is a far better index, and taken in connection with observed pressure seems to be an excellent one with high humidity and low pressure.

From Table 3 it is evident that pressure change is by far of the greatest significance. A comparison of Tables 2 and 4 shows the lowering effect of pressure rise with low humidity and the uniform effect of pressure fall regardless of relative humidity.

Since these tables refer only to east winds at this station it is not permissible to draw general conclusions as to the probability of rain using pressure as the chief argument, but with the winds under consideration it is plain that the observed pressure is by no means a useful index as to rain in summer.

KALTENBRUNNER'S STATISTICAL METHOD OF FORECASTING.

By ALBERT PEPPLER.

[Abstracted from Das Wetter, September–October, 1918, pp. 133–136.]

A statistical method of weather forecasting, based upon the sequence of weather for a large number of years, was published in 1914 by Kaltenbrunner. The idea underlying his work was that the weather of to-day is a

function of the weather of yesterday; or, "similar weather follows similar weather factors." The so called weather factors are wind direction, state of weather, and current pressure at observation (2 p. m.); barometer change in preceding six hours; current temperature and humidity, the latter only in winter.

Schneider [1] gave the Kaltenbrunner method nine months unprejudiced trial at Vienna, with the surprising result that the forecasting from the weather map gave 75 and 62 per cent, respectively, for cloudiness and precipitation, while the statistical method gave 82 and 76 per cent, being an improvement of 7 and 14 per cent, respectively.

These tables have a practical significance not only for the layman, who may, with a few simple and inexpensive instruments, be able to make local forecasts; but also for the scientific forecaster, who may use it, together with the weather map which shows the broader distribution of weather elements, as a very valuable accessory.—*C. L. M.*

INFLUENCE OF THE SEASONS AND WINDS ALOFT ON THE VARIATIONS OF ATMOSPHERIC PRESSURE AND WIND VELOCITY.

By G. REBOUL and L. DUNOYER.

[Abstracted from Comptes Rendus, Paris Acad., May 12, 1919, pp. 947-949.] [2]

A remarkable degree of accuracy is obtained in forecasting the variations of barometric pressure and wind velocity by means of variations of the winds aloft. The problem is considered first in the case where successive soundings of the upper air show increasing or decreasing wind speeds. A year of observations indicate that the following coefficients of certainty obtain under different conditions:

Season.	Winds increasing with successive soundings accompanies or precedes falling barometer.	Winds decreasing with successive soundings accompanies or precedes rising barometer.	Winds constant with successive soundings accompanies or precedes stationary barometer.
Summer	0.79	0.53	0.76
Winter	0.90	0.90	0.94

Similarly, comparing pressure changes and changes of wind intensity and classifying by wind direction, it is found that the average coefficient of certainty is 0.68 in the case of winds from N., NE., or E.; while it is 0.84 in the case of winds from any other direction. It is pointed out in this connection that the SW. winds are the moist ones, whereas the NE. are the dry winds, and that the moisture bearing qualities of these winds play an important part in pressure distribution.

[1] R. Schneider: "Kaltenbrunner's statistische Methode der Wettervorsussage," Met. Zeit. vol. 34, 1917, pp. 239-246.
[2] See another abstract in *Sci. Abs.*, Aug. 31, 1919, p. 362.

In considering the case in which there are large differences of wind speed between upper and lower layers of the atmosphere, it is found that the following coefficients of certainty exist:

Season.	Strong winds aloft followed or accompanied by fall of barometer.	Gentle winds aloft followed or accompanied by rise of barometer.	No change aloft and barometer stationary.
Summer	0.75	0.53	0.60
Winter	0.82	0.78	0.85

Again classifying by wind direction we find about the same average values as in the first case, 0.65 and 0.80 for N., NE., and E. and other directions, respectively. Thus, the value of this method of forecasting barometric variations is better for SW. winds than for NE.—*C. L. M.*

ON THE FORECASTING OF WEATHER BY MEANS OF FORECASTING TOTAL AMOUNT OF BAROMETRIC CHANGE.

By GABRIEL GUILBERT.

(Abstracted from Comptes Rendus, Paris Acad. Aug. 11, 1919, pp. 295-298.)

As is well known, the controlling factors of good and bad weather lie in the distribution of high and low pressure. Clouds and other devices for forecasting variations of pressure are, therefore, of great value. Several rules have been deduced for this purpose:

1. Wind movement in excess of normal is a prognostic of a rise of pressure, generally proportional to the magnitude of departure from normal.

When there are violent winds throughout the formation, both on the periphery and in the center, the maximum rise of pressure will result; sometimes as great as +30 mm. This value decreases with decrease of wind intensity until a stationary barometer is reached with a normal wind.

2. Wind movement less than normal indicates a fall of pressure, generally proportional to the magnitude of the departure from normal. The uniting of all causes of pressure fall may reduce the barometer by about 40 mm. in France. The greatest fall in 24 hours, 42 mm., was observed on December 8, 1886.

This method [it is claimed by M. Guilbert] is accurate enough to forecast the pressure fall or rise, in the majority of cases, to 1 mm.

[Note: The difficulties in forecasting European weather, which are made apparent in the running discussion in *Comptes Rendus*, between MM. Dunoyer and Reboul on one side, and M. Guilbert on the other, are due to the lack of sufficient ocean reports and to the small size of the European countries, compared with the size of the pressure formations. Hence these difficulties are not so in evidence in America.]—*C. L. M.*

SOME WINTER WEATHER SIGNS IN UTAH.

By J. CECIL ALTER, Meteorologist.

[Dated: Weather Bureau, Salt Lake City, Utah, Nov. 1919.]

SYNOPSIS.—Five storms in an average winter are of sufficient severity to concern the sheepherder or other outdoor worker in Utah; and the meteorological forerunners and advance evidences of these storms are often sufficiently well marked as to enable a careful observer, isolated from access to the daily weather forecasts, to make weather forecasts of sufficient range and accuracy as to assist in the protection of his interests.

An average or typical storm over the Plateau States is described, both from the meteorologist's viewpoint, and with especial reference to the attending phenomena that can be observed in any locality within the field of the storm's influence, by the layman without instrumental equipment, or with limited apparatus. Thus the lone observer, unversed in weather lore, is enabled more intelligently to read the weather signs from day to day.

A number of axioms or the more significant and reliable weather signs furnished by old-time observers in the West, are quoted; and a number of weather proverbs which have been found fairly reliable in Utah are presented, with brief explanations of their relevancy.

INTRODUCTION.

Only twenty out of the hundred days in an average Utah winter bring an appreciable amount of precipitation, considering the State as a whole; and only five bring the equivalent of 2½ inches or more of snow. The atmospheric inclemency during the passage of general storms in Utah lasts from a few minutes to a week or more in any one locality, the average number of consecutive stormy days being two. Thus an abundant opportunity is usually afforded in winter for outdoor activity appropriate to the season, in the cities, the agricultural and mining districts and on the livestock ranges, though this very fact of sustained industrial activity makes the coming of these storms of considerable moment.

Most of these disturbances are indicated on the twice-daily weather maps of the United States Weather Bureau and are mentioned from 24 to 36 hours in advance in the forecasts which are distributed to all places that can be reached promptly; but it is often the isolated industry, solely at the mercy of the weather, such for instance as the ranging of sheep on the remote winter ranges, that is in most urgent need of a foreknowledge of coming storms; and it is this need, growing more acute with the increasing number and value of livestock, the segregation of the range, and with the vanishing of the frontiersman's weather lore, that we hope may at least be partially met in this résumé of weather signs, as well as serving other interests not in touch with the daily weather forecasts.

MECHANICS AND MOVEMENT OF STORMS.

Properly to understand any legitimate premonition or sky sign appearing in advance of weather changes, it will be advantageous to examine the mechanics and movement of a typical storm area. Within the great sea of atmosphere flowing eastward continually across this part of the world appear vast maelstroms or eddies of low atmospheric pressure, which interrupt the local course of the winds, vary the temperature and moisture distribution, and cause nearly all the disturbances or storms.

Ordinarily these cyclones or LOWS, as the meteorologist terms them, slowly rotating counterclockwise, with their own systems of winds, and fields of different temperatures, cloud and precipitation, are carried forward with ever-changing features at an average rate of about 750 miles a day, from the time of their appearane off the Alaskan, Canadian, or United States coasts, or, sometimes, in the interior western part of the United States, until lost on the Atlantic Ocean or in Europe or Asia.

These disturbances are so variable, however, in their speeds, their courses, their areas of cloud and precipitation, the intensity of their winds and rates of precipitation and their temperature values, that simultaneous observations are made each morning and evening at a little more than 200 selected places in the United States by Weather Bureau officials so that the forecasters may note what is taking place within the storm and in what direction and at what rate it is moving. On this information the forecasters base their estimates as to what the storm is likely to do in the immediate future.

Cross section of a supposed ideal storm

MOUNTAINS ARE DISTURBING INFLUENCES.

Probably the most disturbing influence encountered by the surface winds about a LOW or storm center is the general topographical elevation of the western portion of the United States. A storm is fed by its winds, and the mountains, interfering with atmospheric movement, interfere also with the normal development and progress of areas of cloud, high temperature, precipitation, low temperature, and fair skies successively, although the disturbance as a whole is little, if any, affected in its rate and direction of progress.

Thus the storm heralds in the form of clouds blown forward like smoke from a forest fire, the increasing warmth and stiffening southerly winds due to the disturbance, and the increasing atmospheric humidity transported from the ocean are more or less interdependent evidences of storm, and are usually unaccompanied by many of the numerous minor signs that appear over the Mississippi Valley and the Eastern States to warn the resident after the storm has crossed the Rocky Mountains.

The companion of the cyclone or LOW is the anticyclone or HIGH, producing the opposite kind of weather, or fair, dry, and cold, with diminished wind movement. Someone has well said: "The weather owes its variety to the LOW, and its reputation to the HIGH." Naturally the winds trend, though by no means directly from a HIGH to a LOW, the steeper the barometric gradient the stiffer the wind; thus the position of the various HIGHS on any weather map, and particularly the so-called subpermanent HIGHS off the principal pathway of LOWS, in the southeastern North Pacific and interior of Canada (during winter), controls in a large measure the rate and direction of movement of any near-by LOW, and of its own family of winds.

SUCCESSION OF "HIGHS" AND "LOWS."

HIGHS that fall in line, as many do, and follow a progressing LOW, have a decidedly important part to play in furnishing variety to the weather. With the turn of the barometer from falling to rising, that is, at the passing of the center of the LOW in Utah, the wind whips suddenly from southerly to northwesterly and increases greatly in velocity; the temperature drops very suddenly and precipitation usually begins. The duration and amount of precipitation is dependent largely on the rate of movement and the depth of the LOW, while the abruptness of the termination of the precipitation, clouds and wind, and the abruptness and amount of the fall in temperature depend on the nearness of the HIGH to the LOW, and on the differences in the lowest and highest readings of the barometer. The normal round or sequence of weather for any locality is subject to still further modification as the storm paths vary in distance from the locality.

When neither a HIGH nor a LOW of importance is near, and conditions are fairly stable in Utah, there are few if any opaque clouds excepting possibly a few in the west toward sunset, though the whitish feathery streaks and streamers of cirrus and cirro-stratus, or high, upper clouds, apparently painted onto the blue sky, may be more or less numerous from time to time owing to distant disturbances, or, frequently, to some local conditions.

STABLE WEATHER ROUTINE.

Stable weather also requires a temperature routine reaching a minimum about sunrise and a maximum about mid-afternoon with a gradual trend toward these culminations in the meanwhile; and a maximum relative humidity about sunrise and a minimum about mid-afternoon. The wind also reaches a maximum velocity in mid-afternoon and a minimum in the early morning hours. There is in some Utah districts, notably at Salt Lake City, a light southerly drift from about 10 p. m. until about noon the following day, with a northwesterly trend during the afternoon regularly, as the great easterly stream aloft imparts its velocity and direction through convectional currents to the surface winds.

Any important interruption of this routine is usually an evidence of the proximity of a storm. The rate of the increase in cloudiness, the rate and amount of the abnormal rise in temperature, and the steadiness and velocity of the southerly wind, and the increase in humidity are rough measures of the nearness of the storm. If the wind suddenly backs into the northeast with vigor, as it sometimes does in adjacent parts of Idaho and Wyoming, the storm center is passing to the south of the observer and severe weather usually follows quickly.

The true chinook seldom occurs in any part of Utah, hence the increased warmth at an unusual hour is nearly always the result of a near-by storm. During the prevalence of snow cover the humidity conditions may be misleading; and if the observer is just outside the path of the precipitation area, all the evidences of the storm, except the precipitation, will be experienced, though with diminished intensity.

SIGNIFICANCE OF BREAK IN ROUTINE.

If the temperature does not fall on a clear, quiet night it is usually a sign that an invisible blanket of moisture is not far above the surface of the earth, being a lofty forerunner of storm, checking the rate of radiation from the earth. If at the same time the wind is gaining speed slowly, and coming steadily from some southerly quarter, rain or snow is pretty sure to follow soon. Usually when a storm of considerable intensity is approaching, but still three or four days distant, there is a cessation of the normal eastward atmospheric flow from the Pacific Ocean across Utah, and a resultant decrease in humidity. The humidity will become particularly low, with unusually high temperatures on about the third or fourth day prior to the storm. As the storm approaches, particularly if its center is about to pass to the north of Utah as most of them do, the humidity will then run above the average, being especially high on the day before the storm.

As long as the cirrus or cirro-stratus clouds only partly obscure the blue sky the storm is still usually more than 24 hours distant, no matter how the other signs read. The cloud field becomes lower and denser until the texture on the lower surfaces of the stratus and strato-cumulus clouds appears coarse; then when the cloud roof shows no seams or breaks, the precipitation is very near.

If the cirrus paving begins and later grows less the precipitation area will probably miss the observer, but if the cirrus or muslinlike sky thatches over like sheet silk, and the blue sky disappears entirely, the storm is approaching the observer more directly. The rate of change from upper or feathery, to lower, dense clouds is to a certain extent a measure of the rate at which the storm is approaching. The cirrus streaks or bands may trend in any direction, and the entire cirrus mass may be drifting (with the wind, of course) in any direction, but only when the cloud lines trend in east-west or southeast-northwest directions, and move longitudinally (not sidewise), do they seem to connect up more definitely with a storm that may concern the observer. These cirrus fronds are not usually many hours in evidence before the cirro-stratus obstruct the blue entirely and the sun (or moon) grows pale; then come the lower clouds, and the storm.

SOME CHARACTERISTICS OF THE HIGH.

The clear, crisp exhilarating atmosphere in the anticyclone or HIGH, without the cloud or moisture blanket aloft to check radiation from the naked earth at night, induces abnormally low temperatures. A good blanket of snow covering a large area, being a good radiator, tends to build up a HIGH and to retard or temporarily to prevent its movement. If a clear winter day does not warm up normally, a HIGH or cool wave is near, and the coming night will be colder than the preceding one as a rule.

The coldest part of an advancing HIGH, or the coldest time after a storm, comes after the maximum importation of cold air at the rear of the storm by the northwesterly winds has occurred, and the cloud and the moisture covering aloft has been drawn away exposing the land to intense radiation. This is often the second night after the storm, depending somewhat on the time of day the cloud layer goes away, and on the size of the HIGH.

The snow layer over which a HIGH sometimes recruits its strength also favors the formation of local fogs; there is also a tendency within the unagitated cold midst of a HIGH for morning fogs to form without the aid of the snow layer to provide the cold and moisture. Therefore, as long as the morning fogs continue, fair weather is assured; but after a series of foggy mornings, if the fogs are absent, the HIGH is waning or moving out. The HIGH often causes the fog to rise, or move up the slopes; therefore, if the snow cover or other causes have induced fogs that are

still lingering locally, and are found to be moving down the slopes, it is usually proof that the pressure is falling with the approach of a storm center of some kind.

DETECTING THE CLEARING SKY.

Sometimes one disturbance is followed very quickly by another so that the clearing between them does not present the normal sequence of weather elements attending the more isolated storms. Usually the storm begins to wane, the wind to slacken, and the snow to lessen, and finally ends entirely with a clear sky before the crest of the HIGH has arrived. Thus, the more energetic storms break away and clear up once for all.

If it is clear in the afternoon or evening, leaving a deep blue sky, there will be a cold night, usually the earlier the clearing the colder the night. A great many storms end in the night, in which case the morning clouds, after the storm, are usually of the lower cumulus type, with soft loose edges, and often in a general orderly arrangement across the sky. They are low and seem to be running rapidly. Between them the sky is blue-black and clear, showing nothing above them. If they are coming from the northwest there is some cold weather to follow, but if from the southwest the approaching HIGH and its attendant cold are much less important. A temporary lull in the storm is often easily detected as the sky is less bright, and there is a greater variety and depth of cloud, than in a truly clearing sky. Even before the sky is visible, the soft mosaic-like clouds will show yellowish edges where the sun shines through.

SOME LOCAL SIGNS IN UTAH.

The signs of the coming and the passing of storms are bound to differ somewhat for different localities in the State because of the topographical differences; therefore, each observer will need to learn something of the local evidences of storm in his own locality. A large number of outdoor men have been interviewed on this subject, and some of the information has been incorporated in the foregoing pages; however, a few typical local signs, which may be applicable to other Utah regions and in adjacent States, are given herewith.

Mr. Walter James, of Government Creek, Tooele County, says he has noticed that coronas and halos indicate that a storm is brewing, but the occurrence of the storm at that place is not certain. Sundogs usually precede cold weather, the brighter the spots the lower the temperature; also the more numerous the spots the more severe the cold. If smoke from the chimney falls to the ground a storm is brewing, though this is not a certain sign of storm. Cattle and horses at large on the range will sometimes seek shelter at unusual hours in advance of a storm.

Mr. George McCune, of Mills, Just County, but for many years a herder over western Utah in winter, says storms are always preceded by a strong wind pressure from the southwest; this wind continues sometimes for a week and sometimes for only 24 hours. When the time is short the storm is sure to be severe, and it will usually be a one-night affair, followed by fair and cold weather the next day. The longer the blow the less severe the storm, though more precipitation may come from the slower storms. Before a storm, the clouds must also come down low, and be near and dark.

Mr. Samuel W. Western, of Deseret, Millard County, says that whenever a cloud settles down on a high peak in Antelope Mountains, some 30 miles to the west of Deseret, a storm is sure to follow. An extra-warm day is a sign of storm, especially if the wind blows from the south a day or so. "I will also refer you to the Bible" writes Mr. Western, "Matthew, 16th chapter, verses 1–3, which applies to this region also: 'He answered and said unto them, when it is evening, ye say, it will be fair weather; for the sky is red. And in the morning it will be foul weather today, for the sky is red and lowering.'"

Mr. Alex Matheson, of Parowan, says there will be rain or snow within 24 hours if the sun sets behind a heavy, black cloud.

Mr. Moroni A. Smith, of Salt Lake City, with a long experience on ranges of western and eastern Utah, notices that after it has stormed a few days the weather does not have to do so much threatening to produce precipitation as for the first storm after a long dry spell.

Mr. A. A. Covey, of Salt Lake City, writing of condiditions in southwestern Wyoming, says: "The northeast blizzards are the worst and coldest storms, which drive all unsheltered stock before them. Only three or four such storms occur in a winter. We don't get much northeast wind unless a bad storm is coming. There isn't much warning in the clouds, except that the storm usually follows low drifting clouds, and they occur after a break or warm spell; thawing weather in January always means a storm. Before a storm sheep appear to feel frisky, and they buck and kick up considerably; horses play also. When it is warm in the morning we expect to see water running before night. It gets extremely cold when the entire country is blanketed with snow, and the sky turns off clear and still."

Mr. Thos. W. James, of Salt Lake City, ranging for many years out of Rock Springs, Wyo., says a west wind for 2 or 3 days will fetch a storm; if the wind begins from the north during the storm, it will clear up and get cold, though sometimes it gets cold without much north wind. The worst storms are when the wind gets around into the east and blows hard. It gets terribly cold in a very short time, these being by far the worst storms. The cattle travel around a good deal in all directions, and bawl for one or two days, and coyotes yelp a good deal both day and night, before a hard storm; sheep also jump about considerably."

SOME PROVERBS FOR WESTERN WEATHER.[1]

In most thickly settled regions of the Eastern States where the weather sequences are more definitely marked the weather signs are rather well and favorably known; and thus a beautiful and more or less truthful lore has grown up about the ways of the weather. But many proverbs,[2] originally good, have been transported by a migrating people to regions where they do not apply, a fact of increasing importance over the western Plateau States, where the atmospheric signs require the most corroboration. Many other well-phrased sayings have no place at all in meteorology, such, for instance, as those referring to the phases of the moon, the significance of conditions on any particular day, or any other totally disconnected phenomena.

[1] Weather Folklore and Local Weather Signs, by Edward B. Garriott, Weather Bureau Bulletin No. 294.

[2] Some Weather Proverbs and Their Justification, by W. H. Humphreys, Ph. D. Popular Science Monthly, May, 1911.

Of the vast number of weather proverbs in existence, however, a few have been found more or less applicable to weather sequences in Utah, in addition to those already incorporated in the foregoing pages. The human manifestations of lassitude, indolence, and inactivity, for instance, are associated with warm moist weather and abnormally low atmospheric pressure, especially in the winter, following a spell of high barometer when the air has been dry and sunny, which tends to electrify and to stimulate. Similar physiological conditions are also manifested by many animals.

Men are apt to sleep better, eat more, and be more energetic when the barometer is high. Sheep ascend the hills and scatter in advance of clear weather, but they bleat and seek shelter before a storm. Old sheep are said to eat greedily before a storm and sparingly before a thaw; but when they leave the high ground and bleat much in the evening and during the night, rough weather may be expected. Fires in stoves usually burn less readily, lacking draft, when the barometer is low; at these times perhaps because of the moisture absorbed by the hygroscopic smoke particles, the smoke falls to the ground and the morning fogs move down the ravines. Fogs move up the slope and fires burn with a better draft when the pressure is high. Birds usually fly low when the barometer is low, and many of them fly high in high barometer. When snowbirds gather in flocks and alight on fences and hedges the proverb says, expect a storm.

EVIDENCES OF CHANGING HUMIDITY.

The increasing humidity in the general atmosphere is manifested in many ways other than by clouds. And in case the storm center is passing well to the north of the observer, he may expect the increase in humidity to be followed by a decrease, usually, as the storm influence wanes. Thus, when cumulus clouds are smaller at sunset than at noon, the tendency is for fair weather; and if the cirrus clouds dissolve and vanish, fair weather is indicated. All humidity indications must be pronounced to be dependable in this region. It is not sufficient for the cat to sneeze, and the dog to grow lazy, though these may often be evidences of increasing humidity and temperature and falling pressure; the latter and not the former are the real weather breeders.

Such articles as smoking tobacco and table salt often show this humidity variation; and an oil lamp or lantern may not burn so brightly or lustily in damp weather; the flame snaps and crackles and a sort of fungus excrescence grows from the wicks and the oil is consumed slowly. While the temperature may be trending upward, but is still well below freezing in the early morning the valley frosts will be much whiter and more profuse because of the increased humidity. Odors are more noticeable in a humid atmosphere because perhaps less readily oxidized and dissipated in the more stable and uniformly moist air. For this same reason sound travels farther in a humid air.

Snow crystals in the upper atmosphere, also a forerunner of storms to a certain extent, produce halos or rings around the sun and the moon, by refraction. The Zuñi Indians had a saying that "When the sun (or moon) is in his house it will rain soon;" also, referring to its illusive appearance, "The bigger the ring the nearer the wet."

Local views near the earth are made plainer by a moisture-laden, quiet atmosphere, yet moisture aloft interferes with light waves from the sun, moon, and stars, because of the varying atmospheric density, and the varying amounts of moisture. Small stars are thus blotted out entirely, and the larger ones have burrs around them. Since this makes it appear as if the stars were getting together the proverb has it, "When the stars begin to huddle the earth will soon become a puddle," or a snowdrift, we might add. A night sky well sown with stars is considered a fair-weather sign. "A clear moon is a frost moon;" that is, if it is sharply outlined, there is less moisture aloft, and without the moisture blanket the naked earth will grow cold. "Sound traveling far and wide a stormy day will betide" and "The farther the sight the nearer the storm" are proverbs that usually pass as legal tender here.

SKY COLORS AND THE WEATHER.

That oldest and most universally applicable of weather signs which concerns the morning and evening sky colors is fairly reliable in Utah, provided there are good corroborative signs. Even the casual observer can soon learn how to note the intensity and shade of colors about the sun and about the edges of the clouds toward the sun that are significant, for they are usually distinctive.

The great amount of red showing in the sunlight when the sun is near the horizon is due to absorption and interference with the light rays by the heavier dust particles in the lower portion of the atmosphere; also to the dust particles which have become greater in apparent size, due to the condensation of globules of moisture upon them. Without this moisture the dispersion of the bluer rays would be less important and the reds reaching the observer less predominant and brilliant.

A red sunset therefore means that the rising air currents during the warmer part of the afternoon have only at these maximum heights been so cooled that their dust particles show incipient condensation of moisture; that is, that moisture is not very abundant in the atmosphere. The sun setting in a glowing horizon as a big ball of fire, looking like so much new gold, followed by colors slow to fade, is thus a fair-weather assurance.

A red sunrise means that at that time, which is the coolest part of the 24 hours, when there is least convection or lifting of vertical currents by the action of the sun, the air is, nevertheless, more or less laden with moisture. During the ensuing day these lower dust particles will be lifted still higher on the wings of the vertical winds for further condensation, a condition necessary for precipitation. Some proverbs pertaining to these conditions are: "Evening red and morning gray are two sure signs of one fine day." "An evening gray and morning red will send the shepherd wet to bed." "Sky red in the morning is the shepherd's sure warning; sky red at night is the shepherd's delight."

Probably a single one of these signs without the others would not be sufficient to justify a prophecy, but when many signs point somewhat definitely toward a change in the weather, such as have been enumerated, the prophecy is reasonably reliable. Forecasting the weather from local signs only must forever remain much less accurate and of much shorter range as a rule than forecasting from telegraphic reports, yet the casual observer, noting the habits of the wind, the unusual temperature, the humidity variation, the rising or falling air pressure, and the general aspects of the sky, should be able, fairly accurately, to anticipate practically all of the more severe winter storms in this region and to fortify his interests against them.

CLOUDS AS GALE PROGNOSTICS ON THE NORTH ATLANTIC COAST.

By ERNEST S. CLOWES.

[Dated: Syracuse, N. Y., Nov. 21, 1919.]

There having recently been published in the MONTHLY WEATHER REVIEW several articles on the forecasting value of clouds, it seems that the following observations might be of interest to some readers, especially those along the Atlantic coast. While the phenomena referred to here have only been observed by the writer on eastern Long Island, N. Y., it seems as if they might have a fairly wide application.

Northwest gales, usually with clear skies, are frequent along the north Atlantic coast in winter. These often continue for several days, even when the storm center has moved as far east as Newfoundland. A peculiarity of these gales is that they frequently abate around sunrise, the wind falling to a gentle or light breeze. If the sky is then cloudless or if the clouds are high or are distributed without reference to the coast line the gale is over; but if, on the other hand, there is a long bank of St.Cu. over the ocean and parallel to the coast while the rest of the sky is clear the wind will increase to gale force an hour or so after sunrise and blow hard all day. The writer has observed this condition during five winters, and without having kept notes on it would say that it was a very accurate indication indeed of the weather and especially of the wind for the coming day. It would seem to be due to the fact that when the gale is over the upper winds are light and probably relatively warm but that when the abatement is merely temporary the cold NW. wind is still blowing not far above the surface, and clouds are formed from the convection and perhaps mixture of it with the relatively warm moist air rising from the sea. Such clouds disappear during the forenoon, when the lower air has become well mixed.

Another local weather sign equally good in winter is a greenish-yellow sky at sunset with the western sky largely covered with patches of dense St. or St.Cu. with sharp, hard outlines. The greenish-yellow sky at sunset is indicative of very clear air, favorable to strong nocturnal cooling, while the patches of dense St. or St. Cu. with sharp, hard outlines are formed both by eddy action set up by the surface irregularities in a strong wind, and by the thermal convection resulting from the steep temperature gradient produced by the rapid arrival of cold air above the slower-moving surface air. Such a sunset with the wind somewhere between SW. and NW. even if it be only a light breeze almost always means a NW. gale before morning accompanied by a drop in temperature approaching or equalling a cold wave.

While the writer has not had the opportunity to observe these phenomena elsewhere than on Long Island, it seems to him that as they are probably due, especially the former, to conditions prevailing generally along the coast in winter they should be of general application over that region and that it would be of interest to know if they have been noted by other observers. If verified they should be of some value to ship masters and others out of touch with the daily forecasts.

THE SCINTILLATION OF STARS AND THE FORECASTING OF WEATHER.

By M. MOYE.

(Abstracted from Société Languedocienne de Géographie Bulletin, Montpellier, vol. 41, 1st and 2d quarters, 1918, pp. 37-39.)

Due to the variable refraction of starlight in passing through layers of air of greater or less turbulence, it is suggested that a simple means of forcasting local weather is to be found in observing the degree of twinkling or intensity of scintillation. The proposal is simply to observe on a certain scale the degree of scintillation and the current weather. The best scale consists of four grades, such as none, feeble, average, or intense. Then, by comparing the observation with what occurs the next day or the second day following, it may be possible to obtain a fairly reliable means for forcasting changes of weather. It is suggested that observations should not be made either at the zenith or at the horizon, as the scintillation is, respectively, less than or greater than normal; also it is well to restrict oneself to the stars of the first and second magnitudes, as they will indicate the conditions well enough.—*C. L. M.*

THE FLOOD MONTHS IN THE UNITED STATES.

By ALFRED J. HENRY, Meteorologist in Charge River and Flood Division.

[Dated Nov. 10, 1919.]

It is a matter of some interest to inquire into the months and seasons of greatest flood frequency in the rivers of the United States. The records used in the inquiry are found in the system of river gaugings maintained by the U. S. Weather Bureau for the period 1875 to 1918, although a considerable portion of the results is based upon a smaller number of years. The plan followed was to average the high water for each month of the year and to select the month which had the greatest average high water and to consider that month as representing the month of greatest flood frequency. As a rule, the highest water observed at any station for the term of years considered falls within the month of greatest flood frequency, although there are exceptions to this rule. In a few cases the greatest flood of record occurred previous to the beginning of systematic gaugings, but these floods have been generally excluded from the inquiry. The difference between the mean monthly high water and the absolute highest for the period of observations gives a rough measure of the amplitude of the floods at the various stations.

There appears to be a well-defined season of high water which varies slightly for the different parts of the country. These variations will now be discussed.

On the Pacific coast the height of the rainy season falls in midwinter, and naturally floods due to heavy rains in the lowlands and melting snow in the mountains occur in any one of the three months January to March, inclusive.

The annual flood in the two great rivers of the Pacific drainage—the Colorado [1] and the Columbia [2]—are due to melting snow on the higher elevations of those watersheds. These floods pass into the lower reaches of the streams in June. The winter rains of the Pacific coast States do not greatly affect either the Colorado or the Columbia.

The snow fields of Colorado and Wyoming supply the greater bulk of the water that forms the lower Colorado flood, and although the mouth of the Columbia is about 1,000 miles north of the mouth of the Colorado, the headwaters of both streams are much nearer each other, and snow melting on the higher elevations begins almost simultaneously.

The water of melting snow which passes down the rivers that head on the eastern slope of the Rockies is largely withdrawn for irrigation purposes and the remainder is not sufficient to produce floods. The Rio Grande, for example, is in flood in New Mexico and in the extreme western Texas most frequently in May. Below El Paso, Tex., however, the flood season occurs in September and October, and is due very largely to heavy rains over the watersheds of rivers which enter the trunk stream on its right bank. On the occasion of tropical storms which pass inland from the Gulf of Mexico (e. g. September, 1919) very heavy rain is precipitated over the basins of the San Juan, the Salado, and the Conchos Rivers of Mexico. The run-off from these streams, owing to the topography and sparseness of vegetal cover, is unusually large. Below Laredo, Tex., the Rio Grande overflows its banks and agricultural interests suffer largely as a result.[3]

The rainfall between the 100th meridian of west longitude and the eastern foot hills of the Rocky Mountains is not sufficient to produce floods in the streams of that region. Directly to the eastward of that meridian extending from Texas north-northeastward to Illinois there is a well-marked flood season in May and in the middle Missouri Valley in May and June. In the early days floods in the Missouri River in the States of Nebraska, Kansas, and Missouri were ascribed in the popular mind to the melting of snow in the Rocky Mountains. Various Weather Bureau officials stationed along the Missouri have pointed out the fallacy of this idea and the great flood of 1903 and lesser floods in subsequent years due to rainfall over the States of Kansas, Nebraska, Iowa, and Missouri have clearly established the fact that floods in the middle and lower reaches of the Missouri in late spring are due solely to the rainfall of those States.

In the east Gulf drainage the month of greatest flood frequency is March. This is also true of practically the whole area east of the Mississippi. The annual flood in the Mississippi proper above Cairo occurs most frequently in May and June and is the result of heavy rains over northeastern Missouri, eastern Iowa, southwestern Wisconsin, and northwestern Illinois. When the rains occur synchronously with the runoff from melting snow in Minnesota and Wisconsin the intensity of the flood in the middle Mississippi is greatly increased.

The Ohio spring floods occur in March and the output from this river is the main factor in causing floods in the Mississippi below Cairo. The intensity of lower Mississippi floods depends upon several conditions, viz., the initial stage of the river, the magnitude of the Ohio flood, and the volume of water contributed by the western tributaries below the Missouri. Flood water from the Missouri rarely reaches the lower Mississippi unti after the Ohio floods have run out. Thus it happens that floods in the Mississippi above St. Louis occur with great frequency in May and June while the month of greatest frequency below St. Louis is April.

In the Atlantic drainage south of New England, March is the month of greatest flood frequency with the single exception of the headwater streams which form the Santee and Great Peedee of the Carolinas where average high water of February is greater than March.

In New England floods are more frequent in April than March and there are occasionally severe floods due to heavy rain in the autumn months.

[1] Cf. F. H. Brandenburg, The Colorado River, MONTHLY WEATHER REVIEW, May, 1919, 47: 309-311.

[2] Cf. E. M. Keyser. Annual rise of the Columbia River, MONTHLY WEATHER REVIEW October, 1917, 45: 509-511.

[3] Cf. MONTHLY WEATHER REVIEW, Sept., 1919, 47; 674.

FLOODS ON LOWER RIO GRANDE.

By ALFRED J. HENRY, Meteorologist.

[Dated: Weather Bureau, Washington, Nov. 26, 1919.]

The great extension of irrigating works throughout the lower Rio Grande valley has made intensive agriculture possible in large portions of Starr, Hidalgo, and Cameron counties, Texas. The recent overflow of the river and the destruction of crops with very considerable damage to irrigating works has again drawn attention to the frequency of destructive floods in that part of the river basin.

The Rio Grande rises in the mountains of southwest Colorado at an altitude of more than 10,000 feet above sea level, flows in a general southeasterly direction for 1,800 miles and empties into the Gulf of Mexico at Brownsville, Tex. From its source to El Paso, Tex., a distance of 740 miles, the fall is 8,300 feet and from El Paso to the mouth—1,030 miles—the fall is 3,700 feet. In that section of the river below Laredo, Tex., the fall is much smaller and in the last 100 miles of its course is probably less than a foot per mile. The banks of the river at Laredo and thence upstream to El Paso are generally high—35–40 feet—and the river flows through a very sparsely settled region, hence the opportunity for damage by flood is very small. In the lower reaches of the stream the banks are only about half as high as at Laredo and while the normal flow is always well within its banks, yet, at times, the fluctuations of flow are very great.

The only tributary of consequence on the left bank is the Pecos River of Texas. On the right bank, however, the following-named streams join the main river below Presidio, Tex.—Conchos, Salado, and San Juan.

It so happens that tropical storms which strike the Gulf coast in the vicinity of the mouth of the Rio Grande generally dissipate in torrential rains over northern Mexico. Owing to the highly diversified topography and the sparseness of the vegetal cover on most of this region the run-off is very great and practically all of it comes from the right bank. There are two flood seasons, on the Rio Grande, viz, the late spring and early autumn. The first comes generally in May, when the run-off from melting snow reaches its maximum. Heavy rainfall over the watershed in southern Colorado and New Mexico is quite apt to cause floods in the river in those States notwithstanding the fact that considerable flow is diverted for irrigation. A serious flood in the lower river is rarely caused by an up-stream flood unless heavy rain should fall in the lower watershed concurrently with rains in west Texas and New Mexico. The autumn flood is confined almost wholly to the lower river and may be considered as the major flood of the year. It is an aftermath of the tropical storms or West Indian hurricanes which occasionally strike the coast in the vicinity of the mouth of the Rio Grande as above stated.

There are no bridges across the Rio Grande below Laredo and no permanent object upon which to install a river gage, hence it has been with the greatest difficulty that a river gage has been maintained for any length of time at the points where overflow takes pace. Continuous gagings have been made at Rio Grande City, Tex., for a period of but 6 years. Unofficial information gleaned mainly from press dispatches and unpublished manuscript reports from the flooded regions enables us to list the destructive floods in the lower Rio Grande in the following paragraphs:

SPRING FLOODS.

June, 1903, flood.—A level of 19.5 feet said to have been reached at Roma, Tex., and a rise of 15 feet occurred at Fort Ringgold (Rio Grande City).

May, 1905, flood.—This flood was confined to the upper reaches of the stream in New Mexico and extreme west Texas.

AUTUMN FLOODS.

September–October, 1904, flood.—This flood was due to heavy rains over the watershed in New Mexico and also over the greater portion of the Rio Grande Valley in Texas, especially in September. At Rio Grande City, Tex., the river overflowed its banks from September 16 to 22, resulting in the complete destruction of all crops planted along the river valley and a number of small shacks or huts * * *.

August, 1909, flood.—This storm caused high tides on the coast of Texas and considerable damage by wind and water in the lower coast country. At Corpus Christi a wind velocity of 56 miles per hour was recorded on the 27th of August. The attending precipitation was exceptionally heavy, especially in northern Mexico, where it inundated the country, causing much loss of life and property and much suffering. The lower Rio Grande rose higher than known for years and flooded the lowlands for miles, resulting in an interruption of traffic and communication and doing other damage. At the close of the month the river had begun to recede at Sam Fordyce, but continued at high-water mark below that place.

September, 1910, flood.—Mission, Tex.—On September 14, 5.65 inches of rain fell at Mission in 24 consecutive hours, and between Mission and Brownsville the rainfall for the corresponding period was much heavier. The river reached flood stage on the morning of September 19, when it was 26 feet 10 inches above the lowest known water this year. There being no river gage it was difficult to ascertain how this year's flood compares with that last year, but from those who have been close observers of the river for many years it is learned that the high water of 1909 exceeded that of this year by about 4 feet.

September, 1919, flood.—This flood was due to heavy rains that fell in connection with the tropical storm of September 14–16. The rise at Eagle Pass, Tex., amounted to 27.2 feet in 24 hours on September 16. This rise was followed by a second period of rains and a second flood wave on the 22d, though not so severe as the first. Below Eagle Pass there was but a single crest of 26.2 feet on the Rio Grande City gage on September 26. For additional information respecting this flood see this REVIEW.

The highest stage of record at Rio Grande City, Tex., is 31.2 feet in 1872. Details of this flood are lacking.

Following is a statement of the highest stages each year compiled from various sources for the earlier years and from the regular observations as indicated:

(*The flood stage is 15 feet.*)

Year.	Month.	Highest stage.	Authority.
1872..	.....	31.5	Local reports.
1892..	August.....	20.2	United States Weather Bureau.
1893..	.....	.....	No flood.
1903..	June.....	21.0	Estimated on rise at Roma just above Rio Grande.
1904..	October.....	30.0	Estimated on rise at Fort Ringgold.
1909..	August.....	30.0	Estimated.
1910..	September....	26.0	Do.
1913..	October.....	28.0	United States Weather Bureau.
1914..	October.....	25.5	Do.
1915..	September....	16.8	Do.
1916..	September....	20.8	Do.
1917..	October.....	21.7	Do.
1918..	May.....	23.5	Do.
1919..	September....	26.2	Do.

FLOOD WARNINGS IN NEW ZEALAND.

The problem of flood prevention in New Zealand is dealt with in a recent report by the dominion meteorologist, Lieut.-Col. D. C. Bates, to whom we are indebted for the following notes. The interference of civilization with natural conditions is not usually in the direction of lessening flood damage, clearing and drainage, causing the water to run off quickly, thus increasing the scouring of slopes and deposition of silt in the lower reaches. The effect is to raise the general level of the lower beds and aggravate flooding. The problem of prevention is one which appears only to be soluble as a national task, the reconciliation of conflicting interests being too difficult to achieve on any other lines and the report recommends strongly the organization of both prevention and warnings on a proper basis.

Attention is directed to the abnormal flooding which not infrequently occurs when the winter snows melt, these being entirely disproportionate to the actual amount of precipitation. Apart from snow the run-off is stated to be approximately 25 per cent of the precipitation, a figure which we imagine must be applied only with a very generous margin of uncertainty. Experience in the British Isles shows us that the expression of the run-off as a percentage of the amount of precipitation is misleading, since quite apart from the very great variability at different seasons and under different conditions of soil and weather, recognized by Mr. Bates, it is practically certain that a much larger proportion of run-off occurs when the average rainfall is large than when it is small.

The prediction of floods may be attempted on (a) the weather chart; (b) the records of rainfall in the river basins, and (c) the actual rise of the streams in their upper reaches. Owing to the known uncertainty, especially in respect to locality, in forecasting heavy rain, the first mentioned method is only applicable in a general manner. The second source of information is undoubtedly capable of development by provision of more observing stations and improving means of communicating records, but the actual rising of the river affords the most certain and striking means of forecast, not only for the time but for the height of an inundation.

The report recommends the closer observation of rainfall, the establishment of flood gages, and the formation of a committee of safety or rivers board charged with the organization and administration of flood warnings in consultation with the dominion meteorological service, the public works, and railway departments.—Symons's Meteorological Magazine, Oct., 1919, p. 101.

PRECIPITATION AND RUN-OFF IN THE DRAINAGE BASIN OF THE ODER.

By KARL FISCHER.

[Abstracted from Yearbook of Hydrology of North Germany, Special Communication, Vol. 3, No. 2.]

Records of precipitation and run-off for eleven subdivisions of the Oder drainage basin were maintained for the most part during the period 1896 to 1905. Stream discharges were determined from rating curves based on current-meter measurements. Rainfall records for the determination of the mean precipitation on each area were presumably numerous and complete, but are not given. Records of precipitation and run-off, either annual or monthly, are not given in complete form, but only in the form of averages for five-year periods and for the complete records.

The most important results, perhaps, are the general averages for the different streams which are summarized in the accompanying tabulation. Plotting rainfall against yield, the author finds an approximately linear relation, which holds, however, only in a general way for the different subdivisions of the Oder Basin. The author expresses these relations by means of formulas of the linear type used by Penck—

$$y = 0.702p - 260.5 \text{ year},$$
$$y' = 1.167p' - 181 \text{ winter},$$
$$y'' = 0.512p'' - 118 \text{ summer},$$

in which y is the yield of the drainage basin in millimeters and p the precipitation in millimeters.

These formulas are intended to apply only to the average yield of subdivisions of the Oder basin and not to the yield of any given subdivision in different years.

There are several exceptions which are discussed by the author. Transposing the formulas so as to express water losses in terms of precipitation, the author finds that the water losses decrease as the precipitation increases for the winter season, but water losses increase with precipitation both for the summer season and for the year as a whole.

The paper is accompanied by numerous tables and diagrams, among which may be specially noted hydrographs of monthly precipitation, yield, and water losses at each gaging station. These hydrographs are in general very similar, showing in nearly all cases a minimum of precipitation in January and maximum in July, a maximum of yield in April, and a maximum of water losses in July, and a minimum of water losses in February or March.

Summary of Karl Fischer's gagings in the Oder drainage basin, 1896-1905.

[P= Precipitation in mm. Y= Yield in mm. L= Water losses in mm. Winter= Nov.-Apr. Summer= May-Oct.

Stream and location.	Drainage area (square kilometers).	Winter.			Summer.			Year.		
		P'.	Y'.	L'.	P''.	Y''.	L''.	P.	Y.	L.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. Oder at Ratibor	6,737	285	160	125	551	151	400	836	311	525
2. Malapane	2,037	292	137	155	435	112	323	727	249	478
3. Glacial Netz	4,534	263	137	126	496	131	365	759	268	491
4. Bober	5,938	282	155	127	438	132	306	720	287	433
5. Lansitz Netz	4,232	298	134	164	451	102	349	749	236	513
6. Mountain areas 1+3+4+5	21,441	282	148	134	488	132	356	770	280	490
7. Warthe, at Posen	24,830	221	73	148	337	46	291	558	119	439
8. Netz, at Vordamm	15,872	216	74	142	321	54	267	537	128	409
9. Warthe, at Landsberg	51,893	216	71	145	326	49	277	542	120	422
10. Oder, at Steinau	29,878	254	115	139	460	104	356	714	219	495
11. Oder, at Pollenzig	47,293	250	97	153	427	85	342	677	182	495
12. Oder, at Hohensaathen	109,564	233	81	152	375	65	310	608	146	462

COMMENT.

It is unfortunate that the author has not presented monthly or at least annual results in detail. It appears probable that the relation of precipitation to run-off and water losses could have been better established for this drainage basin from an analysis of the results for individual stations, by the method of group means, than by a comparison of the pentad means for different stations. The latter may include in a single mean the results for years of excessive and years of deficient precipitation. It is pretty well established that the relation of precipitation to run-off is not linear as most European investigators following Penck have assumed it to be. The method of determining the relation of precipitation to run-off by comparing average results for areas representing different subdivisions of a larger drainage basin, as used by the author, is novel. Perhaps this method has not hitherto been used, because it is not generally applicable. The fact that it does apply reasonably well to the Oder drainage basin is undoubtedly due to the marked similarity of meteorologic conditions, especially as regards distribution of rainfall over the different subdivisions of the Oder drainage basin. However, there must be an appreciable difference in topographic and agricultural conditions affecting run-off in the different subdivisions of the area which is not taken into account by the author.

The author's use of hydrologic winter and summer seasons beginning with November and May, respectively, is to be commended.—*R. E. Horton.*

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C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

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SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING OCTOBER, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in Charge.

[Dated: Solar Radiation Investigations Section, Washington, Nov. 26, 1919.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that radiation measurements averaged below October normal values at Washington and Lincoln, where the month was an unusually cloudy one, and slightly above normal at Madison and Santa Fe.

TABLE 1.—*Solar radiation intensities during October, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 3		1.12	1.01	0.90	0.81	0.74	0.65			
7			1.14	1.03	0.92	0.83	0.75	0.70	0.63	
8					1.01	0.91				
11		1.14	1.05	0.96	0.89	0.81	0.75			
20		1.15	1.01	0.89	0.79	0.72	0.66	0.62	0.58	0.53
28		1.21	1.18	1.13	1.06	1.01	0.96	0.91	0.85	0.78
Monthly means		1.16	1.08	0.98	0.91	0.84	0.75	0.74	0.69	(0.66)
Departure from 11-year normal		−0.06	−0.03	−0.04	−0.01	−0.02	−0.06	−0.04	−0.07	−0.07
P. M.										
Oct. 3		1.12	0.98	0.90	0.79	0.70	0.64	0.58		
7		1.28	1.14	0.97						
13		1.25								
16						0.79				
18		1.21								
20		1.15	0.86							
27							0.62	0.59	0.57	
28					0.94					
Monthly means		1.20	0.99	(0.94)	(0.86)	(0.74)	(0.63)	(0.58)	(0.57)	
Departure from 11-year normal		−0.03	−0.12	−0.08	−0.05	−0.09	−0.13	−0.13	−0.10	

Madison, Wis.

A. M.										
Oct. 6		1.31	1.29	1.23	1.17	1.11	1.04			
7	[1] 1.42	1.33	1.24	1.11	1.08	1.01	0.93			
8			1.06		0.81	0.77				
17	[1] 1.46	1.38	1.31	1.23	1.16	1.09	1.03	0.96	0.92	
22		1.14	1.07	1.06	1.01					
23			0.90							
29				1.12	1.02	0.94	0.86	0.79		
Monthly means		1.29	1.14	1.15	1.04	0.98	0.96	(0.88)	(0.92)	
Departure from 10-year normal		+0.03	−0.02	+0.04	±0.00	+0.02	+0.07	+0.11	+0.23	
P. M.										
Oct. 6		1.39	1.31	1.24	1.17	1.10				
7		1.22	1.15	1.08						
11			1.26	1.14	1.00	0.98				
17			1.18	1.11						
31					1.04					
Monthly means		(1.30)	1.22	1.14	1.07	(1.04)				
Departure from 10-year normal		−0.01	+0.05	+0.04	+0.06	+0.06				

[1] Extrapolated and reduced to mean solar distance.

TABLE 1.—*Solar radiation intensities during October, 1919*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Lincoln, Nebr.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 3			1.11		0.90	0.81	0.78			
7		1.33	1.24	1.16						
11	[1] 1.52	1.40	1.27	1.17						
28			1.27	1.02						
29					1.16	1.06				
Monthly means		(1.36)	1.22	1.12	(1.03)	(0.94)	(0.78)			
Departure from 5-year normal		±0.00	−0.08	−0.10	−0.11	−0.12	−0.22			
P. M.										
Oct. 7	[1] 1.45	1.31	1.23	1.12	1.02	0.94	0.87	0.80	0.74	0.70
11			1.24	1.13	1.05	0.97	0.90			
22			1.13	1.04	0.96	0.87	0.82			
28			1.32	1.22	1.13	1.07	1.02		0.92	
Monthly means		(1.31)	1.23	1.13	1.04	0.96	0.90	(0.80)	(0.83)	(0.70)
Departure from 5-year normal		−0.05	−0.02	−0.02	−0.04	−0.06	−0.06	−0.10	−0.03	−0.12

Santa Fe, N. Mex.

A. M.										
Oct. 21						1.28	1.22			
29							1.19	1.13	1.07	1.01
30						1.24				
31						1.16		1.10		
Monthly means						1.23	(1.20)	(1.12)	(1.07)	(1.01)
Departure from 7-year normal						+0.04	+0.04	−0.01	−0.03	−0.06
P. M.										
Oct. 3		1.54	1.51							
10				1.33	1.29	1.18				
17				1.34		1.19				
21	[1] 1.62	1.52	1.46	1.36	1.30	1.18	1.15			
22					1.25	1.17	1.09			
28					1.27	1.23	1.19	1.15		
Monthly means		(1.53)	(1.48)	1.34	1.28	1.19	1.14	(1.15)		
Departure from 3-year normal		+0.06	+0.09	+0.03	+0.04	+0.03	+0.04	+0.13		

[1] Extrapolated and reduced to mean solar distance.

Table 3 shows a deficiency of radiation at all three stations, amounting to 21 per cent of the October normal at Washington, 19 per cent at Lincoln, and 13 per cent at Madison.

The skylight polarization measurements made at Washington on 4 days give a mean of 55 per cent, with a maximum of 63 per cent on the 28th. At Madison, measurements made on 7 days give a mean of 66 per cent, with a maximum of 71 per cent on the 6th. These are average values for October for Madison, but are below the average for Washington.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Oct. 3	15.11	16.79	Oct. 6	7.29	8.81	Oct. 3	12.68	17.37	Oct. 3	3.81	4.57
7	9.14	11.38	7	6.50	6.76	7	6.76	7.57	10	4.57	4.57
8	3.81	8.48	8	7.29	9.83	11	3.81	5.16	17	4.75	4.75
11	14.60	15.65	11	3.30	4.37	22	5.56	9.47	21	1.96	1.96
13	5.16	7.57	17	3.99	4.57	28	2.36	3.30	22	2.87	2.49
16	16.20	14.60	22	5.16	7.04	29	2.74	6.02	28	3.00	3.00
18	5.56	8.18	23	6.76	9.14	.....	.....	.....	29	3.45	3.45
20	5.36	8.48	29	3.45	4.95	.....	.....	.....	30	5.79	3.00
27	14.10	16.79	31	10.59	4.57	.....	.....	.....	31	3.99	2.36
28	16.20	7.57	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3.—*Daily totals and departures of solar and sky radiation during October, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	77	73	300	−256	−213	− 64	− 256	− 213	− 64
2	180	152	433	−149	−131	73	− 405	− 344	9
3	395	133	361	69	−147	4	− 336	− 491	13
4	296	94	125	− 27	−182	−228	− 363	− 673	− 215
5	230	106	428	− 90	−167	78	− 453	− 840	− 137
6	199	408	441	−118	139	96	− 571	− 701	− 41
7	416	380	460	103	115	119	− 468	− 586	78
8	410	356	55	100	95	−281	− 368	− 491	− 203
9	140	264	378	−167	7	46	− 535	− 484	− 157
10	342	257	369	39	5	42	− 496	− 479	− 115
11	331	369	484	31	121	161	− 465	− 358	46
12	48	358	410	−249	114	92	− 714	− 244	138
13	390	227	96	97	− 13	−218	− 617	− 257	− 80
14	66	143	104	−224	− 93	−205	− 841	− 350	− 285
15	221	124	75	− 66	−108	−229	− 907	− 458	− 514
16	310	317	332	25	88	32	− 882	− 370	− 482
17	179	356	418	−104	129	123	− 986	− 241	− 359
18	328	220	314	47	− 4	23	− 939	− 245	− 336
19	327	128	123	48	− 94	−163	− 891	− 339	− 499
20	363	121	409	87	− 98	127	− 804	− 437	− 372
Decade departure	.....	.....	.....	.....	.....	.....	− 308	− 42	− 257
21	248	182	234	− 26	− 35	− 43	− 830	− 472	− 415
22	264	298	258	− 8	84	− 15	− 838	− 388	− 430
23	38	254	46	−232	42	−222	− 1,070	− 346	− 652
24	61	78	53	−207	−131	−211	− 1,277	− 477	− 863
25	97	36	56	−169	−171	−204	− 1,446	− 648	− 1,067
26	155	85	103	−109	−120	−154	− 1,555	− 768	− 1,221
27	249	20	76	− 13	−182	−177	− 1,568	− 950	− 1,398
28	280	144	259	20	− 56	9	− 1,548	− 1,006	− 1,389
29	167	298	88	− 91	100	−158	− 1,639	− 906	− 1,547
30	86	75	51	−170	−121	−192	− 1,809	− 1,027	− 1,739
31	220	242	220	− 34	48	− 20	− 1,843	− 979	− 1,759
Decade departure	.....	.....	.....	.....	.....	.....	− 1,039	− 542	− 1,387
Excess or deficiency since first of year	.....	.....	.....	Gr. cal.	.....	.....	− 6,842	− 4,636	− 4,293
	.....	.....	.....	Per cent	.....	.....	− 6.0	− 4.2	− 3.4

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Director, Astrophysical Observatory.

[Dated: Smithsonian Institution, Washington, Nov. 24, 1919.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in September, 1919, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919. for statements of the arrangement and meaning of the table.

The observations during the month of September are wholly comparable with those made in the months of July and August, having been made largely by the new method which was described in the last two of the above citations from the REVIEW. It will be noticed that the observations for September are uniformly lower than those for August, the September average being approximately 1.93 and the August average approximately 1.95 calories per square centimeter per minute.

Date.	Solar Const.	Method.	Grade.	Transmission coefficient at 0.5 microns.	Humidity.			Remarks.
					ρ/ρ_{sc}.	V. P.	Rel. Hum.	
1919.								
A. M.	*Cal.*					*Cm.*	*P. ct.*	
Sept. 1	1.930	M_3	S—	0.869	0.741	0.05	7	Cirri in south and east.
2	1.895	M_3	S—	.867	.642	.06	9	Cirri in east.
	1.917	M_2						
	1.912	W. M.						
P. M.								
Sept. 3	1.917	M_3	U+	.865	.502	.22	14	Cirri scattered about sky in a. m. Cirri in east and south in p. m.
	1.930	M_3						
	1.926	W. M.						
A. M.								
Sept. 4	1.941	E_o	E—	.858	.527	.15	20	Cirri in south.
	1.947	M_3						
	1.938	M_2						
	1.941	W. M.						
5	1.918	M_3	S	.865	.572	.15	17	
	1.935	M_2						
	1.929	W. M.						
6	1.934	M_3	S	.868	.616	.10	12	Some cirri in east below sun.
	1.939	M_2						
	1.937	W. M.						
7	1.920	M_3	S	.871	.691	.06	8	Some cirri in east.
	1.939	M_2						
	1.933	W. M.						
8	1.929	M_3	S—	.867	.611	.11	12	Some cirri in east.
	1.957	M_2						
	1.943	W. M.						
9	1.941	E_o	VG—	.855	.563	.10	13	Cirri scattered about sky.
	1.919	M_3						
	1.932	M_2						
	1.931	W. M.						
10	1.905	M_3	S	.861	.574	.12	13	Some cirri scattered about south.
	1.929	M_2						
	1.921	W. M.						
11	1.941	M_2	S—	0.865	0.663	0.14	12	Thin cirri scattered about sky.
12	1.878	E_o	VG—	.881	.658	.11	14	Some cirri low in east.
	1.928	M_3						
	1.918	M_2						
	1.915	W. M.						
13	1.946	M_3	S	.876	.748	.09	12	Some cirri in east.
	1.950	M_2						
	1.948	W. M.						
14	1.925	M_3	S	.867	.666	.12	16	
	1.920	M_2						
	1.922	W. M.						
15	1.926	M_2	S—	.858	.652	.10	12	Cirri scattered about sky and near sun at times.
17	1.925	E_o	VG+	.842	.397	.29	32	
	1.932	M_3						
	1.937	M_2						
	1.933	W. M.						
18	1.922	M_3	S—	.864	.579	.16	19	
	1.947	M_2						
	1.939	W. M.						
19	1.945	M_3	S	.872	.690	.12	12	
	1.950	M_2						
	1.949	W. M.						
20	1.947	E_o	VG+	.869	.617	.12	15	
	1.941	M_3						
	1.957	M_2						
	1.948	W. M.						
21	1.950	$M_{1\cdot89}$	S—	.866	.735	.12	10	Scattered cirri preventing observations at M_3.
P. M.								
Sept. 22	1.917	M_3	S	.857	.506	.22	12	Distant cirri in west. Distant cumuli in east.
	1.919	M_2						
	1.918	W. M.						
A. M.								
Sept. 23	1.958	E_o	VG	.835	.493	.13	15	
	1.925	M_3						
	1.940	M_2						
	1.938	W. M.						
25	1.932	M_3	S—	.858	.484	.26	33	Cirri in east, south and west.
	1.916	M_2						
	1.920	W. M.						
26	1.951	E_o	VG+	.861	.681	.09	12	Low cirri in east.
	1.941	M_3						
	1.955	M_2						
	1.951	W. M.						
27	1.908	M_3	S—	.860	.598	.12	14	
	1.927	M_2						
	1.919	W. M.						
28	1.909	M_3	S—	.865	.631	.11	15	
	1.940	M_2						
	1.930	W. M.						
29	1.928	M_3	S	.851	.648	.10	13	
	1.937	M_2						
	1.934	W. M.						
30	1.929	M_2n	S—	.857	.586	.13	13	Thin cirri in east, south and west. Very streaky over whole sky.
	1.912	M_2						
	1.918	W. M.						

WEATHER OF THE MONTH

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY.

Pressure in the Northern Hemisphere in October is highest over east-central Asia with the crest of the high in Siberia; it is lowest in high latitudes with minima in the neighborhood of Iceland and the Aleutians. The belt of high pressure that encircles the Northern Hemisphere in winter begins to assume definite form in October.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY, Meteorologist.

Stormy weather prevailed off the east coast of Japan during the early days of the month but no special reports have been received to indicate that conditions were of unusual severity. The British S. S. *Harold Dollar*, Capt. M. Ridely, from Kobe (Oct. 1) for Vancouver, encountered heavy weather from the 2d to the 6th, the wind at times reaching hurricane force. The lowest barometer recorded was 29.16 inches on the 3d. It is not known as yet whether this storm was of tropical origin.

Vessels in the mid-Pacific experienced winds of gale force on the 7th and 8th, with barometer readings of approximately 29.00 inches.

During the period from the 19th to the 22d a typhoon prevailed to the south and southeast of Japan, several reporting vessels coming within its field of influence. Warnings received by wireless by the British S. S. *Slavic Prince*, Capt. T. H. Burch, from Honolulu for Yokohama, and noted in the weather report received from that vessel, show that at 6 a. m. of the 20th the center was near latitude 20° N., long. 141° E., and that the typhoon was then traveling in a northwesterly direction. At 6 a. m. of the 21st the center was near lat. 27° N., 140° E., direction northeast. Lowest barometer, 27.95 inches. The *Slavic Prince* experienced winds of force 12 from the southwest on the 22d and the barometer dropped to 28.94 inches, observed reading. Ship's position at this time, latitude 30° 41′ N., longitude 149° E.

The British S. S. *Crown of Cadiz*, Capt. Y. S. Gyve, from Honolulu for San Francisco, encountered a northwesterly gale on the 17th and 18th, when in latitude 36° 50′ N., longitude 124° 50′ W., during which the wind reached force 10. The lowest barometer observed was 29.59 inches, on the 18th.

NORTH AMERICA.

By A. J. HENRY.

Current reports thus far available indicate that October, 1919, was true to its general character as a month of transition only in certain parts of the area under observation; in other words, summer conditions as to temperature and precipitation prevailed over large areas in the south-central portion of the United States, while low temperature and more than the usual amount of snow was the rule, in places at least, in mountain districts of the west as far south as the 37th parallel. The outstanding features of the month were the heavy precipitation over tributaries of the Mississippi in the West Gulf States and the severe cold in the Dakotas and the northern tier of States westward to the Rocky Mountains.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was considerably above the normal at land stations on the American coast from Newfoundland to Florida, and also along the coast of Europe and in the Bermudas; in the Azores it was somewhat lower than usual, and in consequence the average gradient from the Azores HIGH toward the Icelandic LOW was comparatively slight, and on a number of days this reversal of normal conditions was responsible for light to moderate easterly winds, instead of the usual westerlies, over the eastern section of the steamer lanes.

On October 4 there was, as shown on Chart IX, a well-developed LOW central near latitude 42°, longitude 47°. The observer on the British S. S. *Bardic* states in the storm log: "Gale began on the 4th; lowest barometer 28.94 inches at 9 p. m. on the 4th; position 42° 16′ N., 45° 17′ W. End of gale on the 6th; highest force 12; shifts of wind near time of lowest barometer reading, S–SE. to N–NE." Between the time of observations on the 4th and the 5th the movement of this storm was slight, although it had increased considerably in intensity and extent, and on the 5th, as shown on Chart X, a number of vessels in the vicinity encountered violent gales. During the next 24 hours the easterly drift was hardly noticeable, and on the 6th (see Chart XI) the center was near latitude 44°, longitude 38°, with no material change in the wind velocities since the previous day. Mr. H. T. Rutherford, second officer of the American S. S. *William N. Page*, stated in an interesting report of this storm that it was encountered by the vessel while en route from Philadelphia to Rotterdam, and caused considerable damage to the ship and injury to a number of the crew, and if it had lasted 12 hours longer the vessel would never have been able to hold out against it.

From the 6th to the 13th the pressure was well above the normal in the vicinity of the south coast of Iceland, and below normal at the Azores, while there was a well-developed HIGH between the 30th meridian and the European coast during the greater part of this period.

On the 9th and 10th a LOW of limited area was central near latitude 45°, longitude 42°, and gales of from 50 to 65 miles an hour were reported from vessels in the vicinity. On the 14th there was a second disturbance in the same locality, and the observer on the British S. S. *Marengo* states in the storm log: "Storm began on the 13th. Lowest barometer reading 29.45 inches; position 46° 13′ N., 40° 55′ W. End of gale on the 16th. Highest force of wind, 12." The storm area extended unusually far south, as vessels near latitude 37°, longitude 44° reported northwesterly gales of 50 miles an hour. This LOW moved slowly eastward during the period from the 14th to the 17th, gradually decreasing in extent, and on the latter date the center was near latitude 44°, longitude 55°, moderate to strong gales being reported by a few vessels near the center.

From the 18th to the 22d the pressure distribution between the Azores and the north was more nearly normal, and light to moderate winds were the rule in the intermediate region, with the exception that on the 21st a LOW covered a limited area near the 50th parallel and 25th meridian, with southerly winds of gale force in the eastern quadrants.

From the 22d to the 28th the general weather conditions were not far from normal, and a number of reports were received from widely scattered positions in the steamer lanes denoting more or less heavy weather at different times during that period.

On the 29th St. Johns, Newfoundland, was the center of a LOW (see Chart XII) that afterwards developed into an unusually severe disturbance, as shown on Charts XIII and XIV for October 30 and 31, respectively. The observer on the Norwegian S. S. *Harald* stated in the storm log: "Gale began on the 29th. Lowest barometer, 28.98 inches at 2 p. m. on the 29th; position 47° 53′ N., 50° 00′ W. End of gale on the 31st; highest force of wind 12." The observer on the British S. S. *Regina* reports as follows: "Gale began on the 29th. Lowest barometer 29.00 inches at 8 a. m. on the 30th; position 46° 14′ N., 44° 00′ W. End of gale on the 31st; highest force of wind, 10." On the 30th the storm area extended from the coast of Newfoundland to the thirtieth meridian, and from the thirty-ninth to the fiftieth parallels. By the 31st this area had contracted somewhat, although very heavy northwest gales accompanied by rain and snow were reported from a limited region in the southwest quadrant of the LOW, which was on that day central near latitude 51°, longitude 42°.

Fog was apparently unusually rare during the month, as in only one 5-degree square was it reported on more than one day.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

BRITISH ISLES.

One of the chief features (one might perhaps describe it as the ruling factor) in the weather of a very remarkable month, was the almost complete absence of the mild and humid southwesterly winds which prevail with so much energy in an ordinary October. * * *

The general rainfall expressed as a percentage of the average was: England and Wales, 59; Scotland, 57; Ireland, 42; British Isles, 55. Taken generally the month was probably one of the driest Octobers of which there is any record.[1]

In London (Camden Square) the month was dull and cold. The rainfall was the lowest for October in the 62 years' record with the single exception of October, 1897. Mean temperature, 45.7°, or 4.4° below the average, and the lowest for October since 1892.—*Symons's Meteorological Mag.*, London, Nov., 1919, p. 121.

HEAT WAVE DECREASES WINE PRODUCTION IN MADEIRA.

[Consul W. L. Jenkins, Funchal, Madeira, Sept. 27, 1919.]

In the middle of August the estimate for this year's wine production in Madeira was 11,000 pipes, or 1,452,000 gallons. From August 21 to 28, however, the island was almost "smothered" by what is locally called a "Leste." This means a wind from the east, which, coming as it does from the Sahara Desert, is extremely warm and is often accompanied by small particles of sand. During this period the minimum temperature in the shade was 70° F. and the maximum 101°. The temperature in the sun was as high as 135°. The grapes dried up rapidly, and although many of them were just about ready to be picked at that time, present estimates place this year's wine production at only 7,000 pipes, or 924,000 gallons, representing a depreciation of nearly 40 per cent on the previous estimate.—*Commerce Reports 718, Nov. 5, 1919.*

FLOODS IN EASTERN SPAIN.

According to statements in the *Times*, London, of October 2 and 4, 1919, heavy floods have occurred throughout eastern Spain following abnormal rainfall and hail. In Valencia it is stated the ricefields were inundated to a depth of many feet and the harvest ruined. The damage caused by the water is estimated to exceed $2,000,000, and over 100 people have been drowned. Thirty villages and the port of Cartagena were isolated and it was necessary to send a Spanish warship with provisions and military engineers to Cartagena where the road and rail communications were cut.—*Quart. Jour. Roy. Met'l Soc., London, Oct., 1919, p. 352.*

[1] Cf. *Nature* (London), Nov. 20, 1919, p. —.

DETAILS OF WEATHER OF THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY.

Cyclones.—Eight principal and a number of secondary cyclones have been plotted on Chart III. The great majority of the cyclones appeared as rather ill-defined barometric depressions over the Canadian Northwest, only two of which, however, can be clearly traced across the continent. As a result cyclonic control of the weather was pronounced in the Northwest, but not elsewhere, probably by reason of the extension of high pressure over southeastern United States.

Anticyclones.—Twelve anticyclones, eight of which appeared in the Canadian Northwest and four on the Pacific coast, have been plotted on Chart II. Seven reached the Atlantic and the remainder dissipated over the continent. No anticyclone penetrated below the 37th parallel. It is interesting to note that none of the North Pacific anticyclones passed across the continent except in a single instance and that was probably due to merging with an Alberta anticyclone in the lower lake region. The dominant control of the weather during the month was anticyclonic except below the 37th parallel.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Dec. 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for October, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

PRESSURE.

The first few days of the month were without notable pressure variations save that barometer readings were generally higher than average over both the Atlantic and Pacific coast districts, and below average in the interior portions of the country. Near the end of the first decade, however, pressure had risen to well above normal over New England and the Canadian Maritime Provinces, had fallen decidedly in the Middle West and was high and rising in the Canadian Northwest.

By the beginning of the second decade, the first type of winter weather had set in over the northwestern States with high pressure, local snows and freezing temperatures in the northern Plains and Rocky Mountain regions. The high pressure moved slowly southeastward but the attending winter weather was greatly modified with its advance, and temperatures soon returned to near the normal in nearly all districts.

During the first half of the second decade pressure again reverted to the type prevailing during the early part of the month, high on the east and west coasts, and low over the interior districts attended by more or less cloudy and rainy weather. The latter half of the decade had high pressure with generally cool and clear weather in most central and western districts, but to the eastward, particularly in the southeastern States, lower pressure and unseasonably warm weather prevailed. The greater part of the last decade of the month had high pressure in the northwestern section and to some extent over New England and the eastern Canadian Provinces, while in the South and Southwest pressure was frequently low, attended by cloudy, rainy weather.

For the month as a whole the pressure averaged above normal throughout the northern districts, over most southeastern States, and generally in the Pacific coast districts, and over practically all portions of Canada. From the middle Gulf States and central Mississippi Valley westward to Arizona and Utah the average monthly pressure was below normal. The excess in pressure was fairly large over portions of the Missouri Valley, and along the Atlantic coast from Florida to the Canadian Maritime Provinces, and the deficiency moderate in the southern Mountain and Plains regions.

High pressure along the Atlantic coast and over the southeastern districts favored warm east to south winds over much of the country east of the Mississippi, and south winds were dominant over the central and southern Great Plains, despite the somewhat higher pressure to the northward. In the Missouri Valley northerly winds were frequent, while over the far western districts they were variable but mostly with westerly components.

TEMPERATURE.

The early part of the month had temperatures well above the seasonal average over nearly all districts from the Rocky Mountains eastward. In fact, the highest temperatures for the month and in many sections, particularly in the more southeastern districts, the highest temperatures ever observed in October, were recorded during the first few days of the month. During this period temperatures were as a rule below normal in the far West. By the middle of the first decade cooler weather had overspread the central valleys, and extended over the more northern districts to the Atlantic coast by the end of the decade. At the same time high temperatures continued in the southeastern States and another cold area had overspread the Northwest with temperatures near zero at points in the northern Rocky Mountains and freezing weather as far south as Kansas. This cold area extended well southward over the Plains region and thence northeastward to the Great Lakes and New England, but no material change occurred in the districts east of the Mississippi and south of the Ohio Rivers where warm weather still continued.

The greater part of the second decade was without marked temperature changes over any considerable areas. Warm weather for the season prevailed very generally over southern and the more eastern districts, while temperatures decidedly cooler than the average prevailed over much of the Northwest.

Early in the last decade of the month severe winter weather overspread the Canadian Northwest and the adjacent portions of the United States. This cold weather advanced slowly eastward during the latter part of the month, giving the lowest temperatures of the month over all northern districts and generally in the Plains region and to westward of the Rocky Mountains. In the southeastern States warm weather for the period of the year continued throughout the decade.

As a whole the month presented remarkable extremes over unusually large areas. In the southern and southeastern States, particularly near the Gulf and south Atlantic coasts, the month was by far the warmest October in 50 years or more, in some cases the means for the month being more than 5° higher than any previous October mean. This is the more remarkable when it is considered that the usual range between months of the same name in these regions for different years is rarely more than a few degrees. At points near the middle Gulf coast the temperature was above normal every day in the month and it is reported that peach trees were in full bloom at the close.

While the southern States were experiencing nearly midsummer conditions, severe winter weather was the rule in portions of the Northwest. In the northern Plains and thence westward and southwestward to the Pacific coast the month as a whole was one of the severest on record for October. In portions of Wyoming and Montana the month was the severest for October in the known history of the States. Heavy snows occurred, and remained unmelted throughout the greater part of the month, the average temperature was from 10 to 12° F. below the normal and in some cases more than 5° F. lower than the lowest previous October record. The deep snow-covering prevented range feeding, and stock was suffering at the end of the month.

PRECIPITATION.

During the early days of October rain fell in most northern districts from the Atlantic to the Pacific, extending southward over the central Plateau region. By the middle of the first decade rainfall was general in the Southwest, the west Gulf region, and from the Mississippi Valley eastward, the falls being heavy in portions of Texas, Oklahoma, and the Mississippi Valley. The latter part of the decade was marked by some snow in the Rocky Mountain regions and by rainfall over most interior sections to the eastward, the falls being heavy at points in the southern Plains. During the early part of the second decade there was local heavy precipitation in the west Gulf States and more or less rain in most sections east of the Mississippi River, also in the central and southern Rocky Mountains and parts of the far Northwest. About the middle of the month and the succeeding few days, widespread and moderate-to-heavy rains fell throughout most central, southern, and eastern districts. Toward the latter part of the second decade precipitation occurred in the Northwest, also in the Southeast and some north-central districts, and unusually heavy snows fell in the northern Rocky Mountain region and adjacent parts of the Great Plains.

At the beginning of the third decade fair weather was the rule in the East, South, and Southwest, but the next few days were marked by precipitation in the northwestern border States and in the South and East. About the middle of the decade rain or snow was general from the middle Mississippi and Ohio Valleys northward and northeastward. During the latter part of the month rather widespread precipitation occurred in the sections east of the Rockies, except some middle and south Atlantic States, with heavy falls in parts of the central valleys and the Lake region.

October, 1919, as a whole, was one of unusually heavy precipitation from the west Gulf States and Oklahoma northeastward to the Great Lakes, where monthly amounts ranged from 5 to 15 inches or more, frequently far in excess of any previous October record. These amounts were as a rule the results not of abnormally heavy rains on particular dates, but of an unusual number of days with moderate falls. The days with rain in many cases, particularly in the Mississippi Valley, were far in excess of the usual October number. In portions of Texas where October is usually a dry month, cloudy or rainy weather was almost continuous.

In southern Florida there was much less rain than usual and there was a very general deficiency in several southeastern sections. West of the Rocky Mountains precipitation was nearly everywhere less than normal, but particularly so in the far Northwest.

SNOWFALL.

Usually heavy and frequent snows for October were reported from many of the mountain districts of the West, and there were likewise heavy falls for so early in the season over the northern border States from Lake Superior westward. From Colorado and Utah northward snows were reported early in the month but the principal falls occurred near the end of the second and early in the last decade of the month, after which the ground remained snow covered in large areas until the end of the month. Considerable snow was reported in the high mountains of California and small amounts occurred in northern New England. The total fall for the month, particularly in Wyoming and Montana, was frequently from 2 to nearly 4 feet.

RELATIVE HUMIDITY.

The conditions during the month were favorable for high relative humidity throughout the entire country, save along the Pacific coast and locally at a few points in Florida and along the northern border. Over the great central valleys, where cloudy, rainy weather prevailed during the greater part of the month, the relative humidity values were far above normal, and like conditions prevailed in portions of the northern Plateau, Mountain, and Plains region where cold weather and a snow-covering prevailed so persistently.

LOCAL STORMS.

Few reports of high winds have been received and damage from storms was slight. About the 28th, high winds occurred over the lower Lakes and to the eastward, especially in New York State. At Buffalo the wind attained a velocity of nearly 80 miles per hour—the highest of record in October at that place.

Average accumulated departures for October, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0–10.		P. ct.	
New England	51.8	+1.6	+15.9	3.33	−0.30	+1.91	7.1	+1.7	80	+ 2
Middle Atlantic	61.2	+5.5	+24.9	2.89	−0.30	−2.79	6.6	+1.9	82	+ 6
South Atlantic	73.2	+9.6	+18.6	2.26	−1.40	−5.70	5.5	+1.5	86	+ 9
Florida Peninsula	80.7	+3.9	+ 1.0	2.60	−3.70	+2.70	4.8	+0.2	77	− 2
East Gulf	75.5	+9.3	+10.6	4.64	+1.80	+8.76	6.0	+2.2	85	+12
West Gulf	71.1	+4.5	− 3.0	9.25	+6.50	+9.65	7.2	+3.5	88	+16
Ohio Valley and Tennessee	63.9	+7.4	+19.5	7.19	+4.60	+2.20	7.1	+2.7	82	+10
Lower Lakes	56.3	+4.0	+22.7	4.20	+1.20	+1.70	6.5	+0.7	79	+ 5
Upper Lakes	49.1	+1.5	+31.2	3.70	+0.90	−2.30	8.0	+2.0	80	+ 2
North Dakota	33.7	−8.8	+20.4	1.12	−0.10	−2.45	5.5	+0.3	74	+ 2
Upper Mississippi Valley	54.0	+1.2	+22.6	4.20	+1.90	+1.90	6.3	+1.8	81	+ 8
Missouri Valley	50.3	−2.4	+20.7	3.23	+1.30	−2.97	6.5	+2.4	76	+10
Northern slope	36.7	−8.1	+17.8	2.13	+1.20	−2.30	5.7	+1.4	73	+ 9
Middle slope	52.9	−2.6	+ 8.4	2.13	+0.60	−3.93	5.6	+2.1	72	+11
Southern slope	63.8	+1.4	− 9.5	1.72	−0.20	+0.20	6.4	+2.7	76	+12
Southern Plateau	60.0	+2.9	+ 8.9	0.64	+0.10	+1.29	2.6	+0.4	51	+ 7
Middle Plateau	44.4	−6.1	+ 6.9	0.86	0.00	−2.30	3.4	+0.1	54	+ 4
Northern Plateau	44.8	−4.6	+10.1	1.20	0.00	−2.70	5.8	+1.2	64	+ 3
North Pacific	49.0	−2.8	+ 7.4	2.10	−1.80	−6.60	6.6	+0.2	83	0
Middle Pacific	57.6	−0.8	− 6.2	0.42	−1.00	−2.80	2.3	−1.5	62	− 5
South Pacific	62.0	−0.8	+ 4.3	0.50	−0.30	−3.70	2.0	−1.1	62	− 5

Winds of 50 mi./hr. (22.4 m./sec.), or more, during October, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Alpena, Mich	28	60	nw.	Pensacola, Fla	29	50	se.
Buffalo, N. Y	28	78	w.	Pocatello, Idaho	8	52	sw.
Do	31	52	sw.	Point Reyes Light, Calif	2	52	nw.
Canton, N. Y	28	60	w.	Do	8	59	nw.
Cleveland, Ohio	28	56	w.	Do	28	52	nw.
Columbus, Ohio	28	50	w.	Do	29	73	nw.
Corpus Christi, Tex	16	56	n.	Do	30	66	nw.
Erie, Pa	28	50	w.	St. Louis, Mo	8	50	s.
New York, N. Y	28	63	w.	Syracuse, N. Y	28	54	w.
North Head, Wash.	28	52	s.				
Do	31	60	s.				

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Nov. 21, 1919.]

SPECIAL FORECASTS.

Special forecasts were issued for the national balloon race which was held at St. Louis, Mo., on October 1. The forecast issued on the morning of the 1st was as follows:

Moderate southerly winds at surface, fresh south-southwest winds aloft period. Conditions will become unfavorable for free ballooning late to-night and Thursday, when there will be showers and thunderstorms to the east and north of St. Louis.

A supplemental or final forecast based on special observations was issued at 2:33 p. m. of the 1st and read as follows:

No change from forecast sent this morning. At noon to-day low central over eastern South Dakota. Pressure falling rapidly eastward to the Great Lakes period. Considered inadvisable for balloons to start this afternoon as they will be carried northward toward the Great Lakes, where they will encounter squalls and thunderstorms late to-night and Thursday. Advise it postponed.

In spite of the unfavorable advices given concerning the weather conditions, the pilots were determined to start as indicated in telegram received from the Official in Charge, Weather Bureau Office, St. Louis, which read:

Latest information given to pilots but they are still determined to start at 6 p. m. to-day. Will wire if decision is changed.

The race, in which there were 10 entries, was won by Ralph Upson in the balloon Goodyear, which made a landing near Durham, Quebec, a distance of 1,020 miles from St. Louis. All contestants were carried north-northeastward toward Lake Michigan, where they encountered thunderstorms and unfavorable weather conditions. One balloon together with its occupants was lost on Lake Huron.

Special forecasts were also furnished twice daily from the 7th to the 31st for the Transcontinental Reliability Race conducted by the United States Army. The route was divided into zones and forecasts for the different zones were sent to the several control stations. The divisions of the route were as follows: Mineola to Cleveland, Cleveland to Chicago, Chicago to Omaha, Omaha to Cheyenne, Cheyenne to Salt Lake City, and Salt Lake City to San Francisco. The forecasts issued the evening of the 9th were as follows:

Salt Lake to San Francisco: Good flying weather, generally clear sky, good visibility, moderate variable winds near the surface probably fresh westerly aloft.

Cheyenne to Salt Lake City: Uncertain flying weather, some clouds, probably snows and poor visibility in the mountains, moderate north and northeast winds near the surface. Upper winds probably southwest and west.

Omaha to Cheyenne: Bad flying weather, low clouds, probably local snows, poor visibility. Fresh and strong northerly winds surface and aloft.

Chicago to Omaha: Rather bad flying weather, clouds, fresh and strong north and northwest winds surface and aloft. Fair visibility.

Cleveland to Chicago: Uncertain flying weather, clouds, occasional showers and probably thunderstorms. Fresh and strong southwest and west winds surface and aloft.

Mineola to Cleveland: Bad flying weather, clouds, showers and squalls. Fair visibility. Strong south and southwest winds surface and aloft.

That these forecasts served a useful purpose and that such are essential to the successful conduct of aerial navigation is evidenced by an extract from the Air Service news letter of October 25, 1919, as follows:

Lieutenant Maynard's wonderful time was due to the fact that he took advantage of the splendid service rendered by the Weather Bureau in sending the weather forecasts to all of the control stops. If he had been informed that the weather would be bad for the next control stop, he would immediately take off and get to this stop before the storm had approached. This enabled him to gain a distinct advantage over the other participants at the very outset of the race.

Special forecasts were issued daily for the Aerial Mail Service of the Post Office Department and numerous requests for special forecasts were answered.

WASHINGTON FORECAST DISTRICT.

Cold-wave and frost warnings.—On the morning of the 7th frost was reported in upper Michigan, on the following morning in the lake region, the north Atlantic States, in West Virginia, and in portions of the middle Atlantic States, and on the morning of the 9th in the north Atlantic States, warnings for which had been previously issued. On the morning of the 11th warnings for frost were issued for portions of lower Michigan and for temperatures near freezing in upper Michigan, and on the following morning for frost for lower Michigan if weather cleared and for freezing temperatures for upper Michigan. The conditions which occurred justified the advices. On the 12th frosts were forecast for the region of the Great Lakes, the States immediately north of the Ohio River, northern and western Pennsylvania, and the interior of New York and New England. Frosts occurred substantially as indicated in the warnings, except that the weather became cloudy in portions of northern Michigan, thereby preventing the occurrence of frost, and the frost extended into portions of Maryland and West Virginia no warnings for which were issued. On the 16th frosts were forecast for lower Michigan and Indiana and freezing temperatures for upper Michigan, both of which occurred as indicated. On the morning of the 18th frosts occurred quite generally in the upper Ohio Valley, the lower lake region and in the interior of the north Atlantic States, on the morning of the 19th in Pennsylvania, Ohio, and West Virginia, and on the 20th in portions of the lake region, the upper Ohio Valley and the north Atlantic States. The conditions indicated were anticipated in the warnings with the exception of the frosts on the 20th, only a portion of which were forecast. Scattered frosts occurred in Ohio and Indiana on the 22d which were not predicted. Frosts or freezing temperatures occurred on the 29th in Michigan, Indiana, Ohio, and western Pennsylvania, warnings of which had been previously disseminated.

Storm warnings.—On the morning of the 6th storm warnings were ordered on the Atlantic coast from Delaware Breakwater to Eastport but, although fresh to strong winds occurred during the day, no gales were reported. On the afternoon of that date warnings were displayed on the northern portion of the Upper Lakes but again the warnings failed of a general and full verification. On the morning of the 8th warnings were ordered for Lake Superior and the extreme northern

portions of Lakes Michigan and Huron for shifting winds probably reaching gale force off shore, and winds of gale force occured as indicated. On the evening of the 8th the warnings were extended to cover Lakes Michigan and Huron and on the morning of the 9th were extended to the Lower Lakes and warnings for strong east and southeast winds probably of gale force shifting to northwest were disseminated to ports on Lake Superior. On the 10th the warnings for the Lower Lakes were repeated and the warnings ordered down the evening of that date. Strong winds were reported on all lakes and gales occurred at a number of points. On the evening of the 22d warnings for winds changing to strong northwest by the following morning, with rain changing to snow and much colder weather, were disseminated for western Lake Superior and the conditions indicated occured practically as indicated. On the morning of the 24th warnings for increasing easterly winds probably reaching gale force with rain and snow were distributed for Lake Superior and at 6 p. m. of the same day were extended to Lakes Michigan, Huron, and Erie. On the morning of the 25th the warnings on Lake Superior were changed to northwest, and southwest warnings were extended to Lake Ontario. Fresh to strong winds with rain or snow occurred generally over the region of the Great Lakes. On the evening of the 27th the following forecast was sent out by radio to vessels on the Great Lakes:

Fresh and strong shifting winds with snow on Lake Superior and rain followed by clearing Tuesday on Lakes Michigan and Huron. Storm of moderate intensity central over Lake Michigan moving northeastward.

During the night winds of gale force occurred on Lakes Michigan, Huron, and Erie. Storm warnings were ordered on the morning of the 28th for Lake Ontario, and information that the winds would diminish at night was disseminated to ports on Lake Erie. Warnings were also ordered the morning of the 28th for the Atlantic coast from Cape Henry, Va., to Eastport, Me., and strong winds and gales occurred over the regions indicated in the advices.

On the afternoon of the 30th storm warnings were ordered on Lakes Superior, Michigan, and Huron, and fresh to strong winds occurred over portions of the Lakes mentioned, but no general gales were reported.

WARNINGS FROM OTHER DISTRICTS.

Chicago Forecast District.—Frost warnings were issued for the Dakotas, eastern Wyoming, and the western portions of Nebraska and Kansas on the 3d and 4th and were partially verified.

On the morning of the 9th a disturbance of marked character was central over Minnesota, while an area of high pressure, accompanied by unseasonably low temperature, was advancing rapidly southeastward over Alberta and Montana, indicating a period of much colder weather for the Chicago forecast district. Accordingly cold-wave warnings were issued for western Minnesota, the eastern and central portions of the Dakotas, southwestern Nebraska, and western Kansas. The warnings were fully verified in the Dakotas only. By the morning of the 10th the crest of the high-pressure area had reached the northern Plains States and warnings of heavy to killing frost were issued for all sections eastward and southward to the limits of the district, except extreme southern Illinois. These warnings were fully verified, except from southeastern Kansas eastward and northeastward over most of Missouri, Illinois, and southeastern Wisconsin, where cloudiness persisted and prevented the formation of frost.

The next warnings were issued on the 16th for the southeastern portion of the district and were fully verified, except in portions of southern Missouri and southern Illinois.

Warnings for the protracted period of unseasonably cold weather in the Northwestern States during the latter part of the month were issued well in advance of the change to colder. In fact, a cold-wave warning was sent to Havre, Mont., on the evening of the 21st when a disturbance was centered immediately to the northward and the sea level pressure was 29.78 inches and the temperature 28° F. The forecast was based principally on the pressure distribution over Alaska, which was favorable for the rapid southeastward advance of a high-pressure area and cold wave over Alberta. By the following morning the barometer had risen to 30.20 inches at Edmonton, with a temperature of 12° F. The cold-wave warnings were then extended to cover all of Montana, North Dakota, and northern Wyoming, and live-stock warnings were sent to the Wyoming and South Dakota stations. During the afternoon and evening cold-wave warnings were issued for South Dakota, Minnesota, western and northern Nebraska, southern Wyoming, and western Kansas, and live-stock warnings for western Nebraska. These warnings were fully verified in Montana and North Dakota, and only partially in the other States on account of the development of a storm of considerable intensity over the northern Plateau Region, with decreasing pressure to the eastward. On the 20th live-stock warnings were issued for Kansas and cold-wave warnings for southwestern Nebraska and northwestern Kansas and Wisconsin. These warnings were not verified, due to the fact that the high-pressure area did not advance southward and eastward as expected.

The last warnings of the month were issued on the 28th, when warnings of heavy frost or freezing temperature were issued for Illinois and southern and eastern Missouri. Killing frost and freezing temperature occurred as predicted in northern Illinois and extreme northern Missouri, but the weather continued cloudy and unsettled to the southward.—*Charles L. Mitchell.*

New Orleans Forecast District.—Frequent heavy rains occurred during the month, rain forecasts being made for Arkansas and Louisiana on 22 dates.

No general storm occurred along the West Gulf coast and no storm warnings were issued.

Cold-wave warnings were ordered on the evening of the 24th for the Texas Panhandle, Oklahoma, and the extreme northwestern portion of Arkansas; the high pressure and cold weather drifted to the eastward instead of moving southward, and while temperatures fell sharply, cold waves did not occur. Cold-wave warnings were ordered on the morning of the 26th for Oklahoma and northern Arkansas, and while there was a sharp fall in temperature, the warnings were not verified.

Frost warnings were issued for northwestern Oklahoma on the 6th; for Oklahoma and the Texas Panhandle on the 10th; for extreme northern Arkansas on the 17th; for Arkansas, Oklahoma, and the northern portion of Texas on the 28th; and for Oklahoma on the 31st. Frost temperatures occurred in several localities. No frosts occurred without warnings.—*I. M. Cline.*

Denver, Colo., Forecast District.—October was notable for the prevalence of moderate anticyclonic conditions in the northern Plateau and Rocky Mountain regions, and correspondingly cool weather in the greater part of this district.

Frost or freezing-temperature warnings were issued for considerable areas in the northern and central parts of the district on the 3d, 4th, 5th, and 6th, owing to the

gradual development of anticyclonic conditions in the northern portions of the Plateau and Rocky Mountain regions. The warnings were justified except in northern New Mexico, where continued cloudiness was unfavorable to radiation and the formation of frost. However, the skies cleared during the night of the 7th–8th, notwithstanding the fact that the barometer fell sharply, and frosts were reported in parts of southwest Colorado and northern New Mexico. An Alberta LOW of marked intensity extended from northern Arizona northeastward on the morning of the 9th, with a rather steep barometric gradient to the northward. Warnings of freezing temperature were issued for the northern and central parts of the district, with a cold wave in eastern Colorado and southwest Utah. Freezing temperatures occurred as predicted, with a fall in temperature of 15° to 20° F. in eastern Colorado and southwest Utah. Owing to continued moderately high barometric pressure on the northeastern slope, warnings of freezing temperature were issued for parts of eastern Colorado on the 15th and 16th and for frosts in northern New Mexico on the 16th. The warnings were justified. Freezing temperature-warnings were again required in parts of Utah, Colorado, northern Arizona and northern New Mexico on the 18th, 19th and 20th as low barometric pressure prevailed in the district, while an anticyclone from the north Pacific had appeared in British Columbia. The warnings were generally justified. On the morning of the 24th the barometric pressure over the district was low, while the front of an anticylcone had reached southern Montana and the area was overspreading Idaho and Washtngton. Freezing-temperature warnings were issued for Utah and eastern Colorado. Freezing temperatures occurred as forecast, attended by snow in northern Utah. Warnings for freezing temperature were repeated for Utah on the 25th as the barometric pressure was still low in western Colorado. The front of the anticyclone spread southward to Kansas, blocking the eastward movement of the LOW. Nevertheless, freezing temperature occurred in Utah. The LOW moved southeastward to New Mexico on the 27th, followed by rising barometer in the Plateau region, and freezing-temperature warnings were issued for the greater part of the district. Interests in Colorado were advised as follows: "Much colder weather to-night with temperatures below the freezing point" and in northern New Mexico "Freezing temperature and frost to-night." Temperature fell 15° to 20° F. in parts of Colorado and a killing frost occurred at Santa Fe, N. Mex. One station in the fruit district in Western Colorado reported a temperature of 11°F. above zero.—*Frederick W. Brist.*

San Francisco Forecast District.—On the morning of the 23d a low pressure area was central over Nevada causing rain generally throughout the north Pacific States and the temperatures fell rapidly during the succeeding 24 hours. On the 24th, with a low pressure area over southern Nevada, the rain in the north Pacific States ceased and killing frosts occurred generally throughout eastern Washington, Oregon, and Idaho. This storm caused the first good rains of the season in southern California and on the 24th they extended north to the Sacramento Valley. The low-pressure area moved slowly eastward and on the morning of the 25th it was over Utah.

The high-pressure area over the northern Rocky Mountain States gradually disintegrated, but the cold weather continued in that region, killing frosts being reported on the morning of the 27th in the Puget Sound country.

Near the end of the month a high-pressure area moved from the north Pacific States to the central Plateau States and in doing so caused cold weather in Nevada and northern California. Frost formed in the San Joaquin Valley during this period. The cold weather that overspread the northern portion of the district during the third decade closed the crop season everywhere in the district except in California.

Frost warnings were issued on five days during the first decade for some one or more places in Oregon, Washington, or Idaho, and they were issued on four occasions during the third decade for localities in California.

A southwest storm warning, the first of the season, was issued on the 31st for Washington seaports, which was verified on Puget Sound and partially verified at the mouth of the Columbia River.—*E. A. Beals.*

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RIVERS AND FLOODS, OCTOBER, 1919.

By ALFRED J. HENRY, Meteorologist in Charge.

[Dated: Weather Bureau, Washington, Nov. 28, 1919.]

Precipitation during October was heavy to excessive over a very considerable area, viz, from northeast Texas to the upper Ohio Valley. (See Chart V.) In parts of this region the rains were frequent as well as heavy and notwithstanding the large absorption by the soil at this time of the year the run-off was heavy resulting in floods of exceptional magnitude for the month in the Ouichita and Red Rivers, particularly the first-named where the flood exceeded the previous high water for October at Camden, Ark., by 10 feet. The floods on both rivers were rather long drawn out by reason of the duration of the rains. Warnings were issued well in advance and revised daily as required by the continued rains. Floods of lesser magnitude occurred in the Osage, Gasconade and Meremec of Missouri, the Wabash and White of Indiana, and freshet stages occurred generally in the tributaries of the Ohio.

As a consequence of these floods the lower Mississippi during the next month or so will carry more water than is usual in the late autumn. If the discharge during November and December should continue abnormally high, the lower river will be in a favorable condition for a spring flood in 1920 should precipitation also be favorable. It is perhaps worthy of note that there has been no flood of consequence in the lower Mississippi since 1916.

Moderate floods also occurred in the Guadalupe, Colorado, Brazos, Trinity, and Sabine Rivers of Texas.

In the Missouri below the mouth of the Osage and in the Mississippi below the mouth of the Missouri both streams rose very suddenly, the 24-hour rise in the former being 9.8 feet at Hermann on the 28th, and 10.7 feet at St. Louis on the 29th.

The advices as to floods issued by the Weather Bureau officials in the flooded districts were timely and of great material benefit to all persons residing in the lowlands affected.

LOSS BY FLOODS.

Owing to the fact that the floods came so early in the year, the scarcity of farm labor and other causes which conspired to prevent gathering of crops already matured, the loss was unusually heavy considering the magnitude of the floods. The crops to suffer most were cotton in northeast Texas and adjoining territory. The rainy weather prevented picking and decreased production, and also caused a deterioration in grade of the cotton already in bloom. In Lamar County, Tex., it is estimated that the loss will be from 8,000 to 10,000 bales. The loss to the corn crop by reason of the much greater area flooded was perhaps the greatest that crop has suffered in many years. A very large acreage of corn in the bottom lands along the Ohio and its tributaries in Ohio, Indiana, Kentucky, Illinois; also along the streams of Missouri, Arkansas, Texas and Louisiana, suffered partial or total loss. In Missouri the rather unusual spectacle was afforded of salvaging corn which was lodged as driftwood along the rivers. The money value of the crops so lost and damaged can not of course be accurately known short of a census of the flooded districts, but it can not fall far short of several million dollars. The table below contains estimates for only a part of the flooded districts.

Flood losses, October, 1919 (incomplete).

District or river.	Tangible property, bridges, highways, etc.	Crops, corn, cotton, and hay.	Live stock.	Value of warnings.
Ouichita	$25,000	$1,719,000	$25,000	
Upper Trinity	15,000			$50,000
Petit Jean, Ark		15,000		
Guadalupe		10,000	2,000	
Colorado				25,000
Brazos		50,000		
Wabash	600	40,000	1,000	200,000
	40,600	1,834,000	28,000	275,000

TABLE I.—*Flood stages in the Mississippi drainage during month of October, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Scioto:	*Feet.*			*Feet.*	
La Rue, Ohio	11	29	29	11.0	29
Wabash:					
Mount Carmel, Ill	15	29	(1)	16.7	31
Osage:					
Warsaw, Mo	22	28	(1)	28.5	29
Tuscumbia, Mo	25	28	(1)	33.8	30
Meramec:					
Steelville, Mo	12	27	28	16.5	28
Pacific, Mo	11	27	(1)	23.4	29
Glencoe, Mo	15	28	(1)	26.5	30
Valley Park, Mo	14	27	(1)	30.7	30
Bourbeuse:					
Union, Mo	10	28	(1)	19.2	30
Ouichita:					
Arkadelphia, Ark	18	12	12	20.5	12
Do	18	23	23	19.3	23
Camden, Ark	30	15	(1)	37.0	17
Petit Jean:					
Danville, Ark	20	12	13	21.5	13
Red:					
Fulton, Ark	28	14	17	29.4	16
Do	28	24	27	29.8	26
Springbank, Ark	29	27	(1)	29.5	29, 30
Sulphur:					
Finley, Tex	24	13	(1)	28.6	27
Ringo Crossing, Tex	20	10	17	24.0	12, 13
Do	20	22	28	25.7	24
Cypress:					
Jefferson, Tex	18	15	19	22.2	16
Do	18	28	30	19.5	28
Trinity:					
Dallas, Tex	25	9	13	30.4	11
Do	25	18	18	27.8	18
Do	25	22	28	36.9	24
Trinidad, Tex	28	14	(1)	38.0	31
Liberty, Tex	25	22	(1)	27.3	31
Sabine:					
Logansport, La	25	23	(1)	32.7	28
Brazos:					
Waco, Tex	27	23	23	28.0	23
Washington, Tex	45	25	26	45.8	25
Colorado:					
Columbus, Tex	28	12	18	34.8	14
Guadalupe:					
Gonzales, Tex	22	12	22	34.1	18
Victoria, Tex	16	8	28	25.1	21

[1] Continued into November.

MEAN LAKE LEVELS DURING OCTOBER, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., November 4, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during October, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.47	580.63	572.50	246.35
Above or below—				
Mean stage of September, 1919	−0.08	−0.18	−0.25	−0.51
Mean stage of October, 1918	+0.04	−0.54	+0.20	+0.35
Average stage for October, last 10 years	−0.15	+0.19	+0.42	+0.57
Highest recorded October stage	−1.09	−2.31	−1.20	−1.46
Lowest recorded October stage	+0.89	+1.03	+1.70	+2.68
Average relation of the October level to—				
September level		−0.2	−0.3	−0.4
November level		+0.2	+0.3	+0.2

[1] Lake St. Clair's level: In October, 575.39 feet.

EFFECT OF WEATHER ON CROPS, OCTOBER, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Farm work was frequently delayed during the month in some central districts as a result of rainy weather and was suspended the latter part of the month by snow and cold weather in much of the northwestern area, while frequent interruptions were caused in the Southwest by rains and wet soil throughout the month. Rainfall was sufficient during the early part of the month to facilitate plowing in some central districts where the soil had been too dry, and this work made better progress in those sections.

Small grains.—In general, the weather during the month was favorable for seeding and for germination of winter grains, except that the first part continued too dry in Kentucky and in portions of the adjoining States, as well as in the lower Great Plains and in the Atlantic coast districts. The rainfall in much of the more western portion of the country during the first week of the month was very beneficial in softening the ground for seeding and in promoting the germination of grain. It was too wet, however, in the west Gulf region during most of the month and there was some interruption by rains in the lower Great Plains the latter part. There was too much rain, also, the latter part of the month in Kentucky, Arkansas, and Tennessee, and the seeding of winter grains was considerably delayed in those States, but, at the same time, rains in the eastern portion of the winter-oat belt put the soil in better condition for seeding in that area. The weather was unfavorable for the harvesting and thrashing of rice in the lower Mississippi Valley and the Southwest and the frequent rains caused some damage to that grain. Winter grains germinated well, came up to a good stand, and at the close of the month were in generally good-to-excellent condition. Some damage resulted to grain sorghums in the lower Great Plains by wet weather. Considerable damage was done to corn by the flooding of lowlands, particularly in the Ohio and Middle Mississippi Valleys and portions of the Southwest.

Corn.—At the beginning of the month the corn crop was out of danger of frost in all central and northern districts and by the end of the first decade of October it was safe in practically all sections of the country. Rainy weather, however, delayed the drying out of corn in many central sections, particularly in the Great Plains and the Western Mississippi Valley States, which rendered it unsafe to crib in large quantities. The rainfall near the middle of the month in the southern drainage area of the Ohio Valley was beneficial to late corn.

Cotton.—Sunshine was inadequate and that there was too much rainfall during October for the proper development of late cotton from the Mississippi Valley westward, and deterioration of the crop resulted while considerable damage was done to open cotton by excessive rains. On the other hand it was too dry for best results in the more eastern portions of the belt, but the rainfall during the second decade was beneficial in the northeast. Picking made very slow progress in the western portions of the belt and during part of the month was entirely suspended, but this work made good advance in the eastern States where weather conditions were more favorable for harvest.

Pastures, truck, and fruit.—Sufficient rain fell during the first decade of the month to improve pastures and ranges in nearly all districts, except that it continued too dry in the Southeast where meadows and pastures deteriorated. Thereafter, the weather was mostly favorable in nearly all sections, but the range was covered by snow the latter part of the month over the upper Great Plains, and much suffering of live stock was reported. Some damage resulted to late truck by frost in the central and upper Rocky Mountain regions during the first week, and it continued too wet in the west Gulf section and was too dry during much of the month in the Southeast, but in other districts truck crops were favorably affected by the weather of the month. More moisture would have benefited citrus fruits in Florida, but the weather was favorable for these crops in California where naval oranges were reported to be setting well.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, October, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	74.4	+10.3	Evergreen	99	1	2 stations	46	19	4.53	+1.72	Robertsdale	11.81	Alaga	0.95
Arizona	57.3	− 3.6	Aztec	100	3†	Colmac	8	19	1.18	+0.20	Williams	5.41	Mormon Lake	2.47
Arkansas	66.6	+ 4.9	Batesville	98	2	Dodd City	33	19	10.90	+8.09	Texarkana	18.28	2 stations	6.31
California	57.6	− 3.5	3 stations	95	11†	Portola	3	29	0.63	−0.82	Blue Canon	3.70	20 stations	0.00
Colorado	41.7	− 3.4	Burlington	90	1	Dillon	−17	28	1.46	+0.14	Cumbres	6.50	Salida	T.
Florida	79.2	+ 6.7	2 stations	98	3†	2 stations	58	20	2.42	−1.94	Lock No. 1	8.87	Ritta	0.04
Georgia	74.6	+ 9.8	Bainbridge	99	5	3 stations	49	14†	2.84	−0.03	Goat Rock	6.43	Valdosta	0.20
Hawaii (Sept.)	74.5	− 0.2	Mahukona	95	29	2 stations	52	20†	3.76	−1.84	Eke Maui	21.50	4 stations	0.00
Idaho	40.8	− 5.0	Glenn's Ferry	87	1	Obsidian	−12	31	1.54	+0.66	Musselshell	4.00	Glenn's Ferry	0.20
Illinois	58.2	+ 3.2	2 stations	95	1	Mount Carroll	21	29	6.93	+4.55	Fairfield	16.00	Macomb	1.30
Indiana	60.1	+ 5.8	Rome	97	1	Hobart	22	29	8.22	+5.75	Worthington	13.94	Hobart	2.72
Iowa	50.7	− 0.1	3 stations	89	2	Inwood	8	28	3.02	+0.56	Delaware	8.65	Sioux Center	0.45
Kansas	54.7	− 1.9	Ellsworth	99	1	3 stations	14	28†	2.16	+0.26	Pittsburg	10.61	Tronsdale	0.38
Kentucky	65.6	+ 7.8	Earlington	98	1	Farmers	35	18†	7.99	+5.49	Pardstown	12.46	Falmouth	4.88
Louisiana	75.9	+ 8.2	2 stations	96	10†	Minden	45	18	8.49	+5.06	Ten Mile	16.12	La Rose (near)	2.00
Maryland-Delaware	62.5	+ 6.1	Western Port, Md.	96	3	Grantsville, Md.	27	13†	3.21	+0.08	Oakland, Md.	6.55	Delaware City, Del.	1.30
Michigan	49.8	+ 1.3	2 stations	88	2†	Humboldt	11	29	4.24	+1.57	Rogers	7.20	Port Austin	2.10
Minnesota	40.1	− 5.2	Winona	88	2	2 stations	−14	26	1.87	−0.31	Grandy	3.77	Ada	0.48
Mississippi	73.3	+ 8.7	4 stations	98	1†	2 stations	40	19	7.32	+4.52	Crenshaw	11.28	Enterprise	2.29
Missouri	58.4	+ 1.4	Caruthersville	98	1	Maryville	17	29	6.74	+3.93	Rolla	14.87	Chillicothe	1.15
Montana	35.3	− 8.6	Crow Agency	82	2	Shelby	−21	25	1.56	+0.58	Glendive	4.57	Fortine	0.22
Nebraska	46.3	− 4.5	3 stations	92	1†	Nenzel	3	28	1.84	+0.26	Westpoint	3.83	Calloway	0.45
Nevada	44.4	− 5.8	2 stations	87	11†	Metropolis	− 5	31	0.64	−0.06	Gold Creek	3.47	4 stations	0.00
New England	50.2	+ 1.7	Bridgeport, Conn.	90	3	Bloomfield, Vt.	11	30	3.55	−0.12	Enosburg Falls, Vt.	7.50	Providence, R. I.	1.49
New Jersey	59.0	+ 4.9	Bridgeton	92	3	Culvers Lake	24	13	3.43	−0.21	Dover	4.97	Northfield	2.01
New Mexico	52.9	− 0.6	2 stations	91	1†	Raton	9	31	1.58	+0.35	Cabeza	5.25	Carrizozo	0.10
New York	62.6	+ 2.7	Avon	90	3	Gabriels	11	8	3.96	+0.66	Salisbury	11.39	Penn Yan	1.69
North Carolina	68.8	+ 9.6	Salisbury	100	5	Wenona	37	20	3.86	+0.59	Murphy	7.45	Southport	0.85
North Dakota	33.5	−10.3	2 stations	84	7†	Zap	−18	26	1.10	+0.10	Fryburg	3.63	Pettibone	0.15
Ohio	59.5	+ 6.1	Waverly	97	2†	Montpelier	25	29	6.29	+3.69	Mulberry	11.19	Cleveland	3.17
Oklahoma	61.9	− 0.3	Buffalo	98	2	Kenton	19	28	7.27	+4.31	Hugo	17.39	Buffalo	0.45
Oregon	46.2	− 4.2	Grants Pass	86	6†	Blitzen	− 6	23	1.89	−0.46	Government Camp	9.52	Silver Lake	0.10
Pennsylvania	57.5	+ 4.9	3 stations	92	3	West Bingham	21	8†	4.77	+1.47	Lycippus	8.04	Philadelphia (d)	2.28
Porto Rico														
South Carolina	73.7	+10.1	Society Hill	101	5	Walhalla	44	14	2.53	−0.59	Monetta	8.43	Pinopolis	0.18
South Dakota	40.4	− 7.0	Howell	90	1	Pollock	−17	28	1.97	+0.24	Spearfish	4.03	Melletta	0.41
Tennessee	68.1	+ 8.6	2 stations	97	1†	Springville	37	18	8.33	+5.69	Rugby	13.17	Rogersville	4.59
Texas	70.3	+ 3.3	Harlingen	98	20	Dalhart	23	27	7.42	+4.94	Jourdanton	17.79	Bovina	0.64
Utah	42.3	− 6.3	St. George	90	.....	East Portal	− 3	28	1.51	+0.30	Millville	5.25	Emery	T.
Virginia	65.6	+ 8.2	2 stations	96	3†	Burkes Garden	30	19	3.27	+0.14	Elk Knob	8.05	Swansonville	1.10
Washington	46.2	− 3.5	Yakima	89	7	Colfax	2	25	1.85	−0.77	Cedar Lake	8.80	3 stations	0.00
West Virginia	62.3	+ 7.6	Moorefield	102	2	Marlinton	28	19	5.84	+3.18	Pickens	11.88	Sutton	2.13
Wisconsin	46.5	− 1.1	Neillsville	85	2	Marshfield	8	29	3.86	+1.30	Lake Mills	7.28	River Falls	2.00
Wyoming	34.7	− 7.7	Spencer	82	1	2 stations	−18	27†	2.30	+0.96	Middle Fork	5.42	Lovell	0.46

* For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52–53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.													
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.			Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.				
																									Miles per hour.	Direction.	Date.											
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	In.	In.		Miles.						0–10	In.	In.					
New England.							51.8	+ 1.6													80	3.33	− 0.3								7.1							
Eastport	76	67	85	30.03	30.12	+ .12	46.0	− 0.6	68	11	52	26	30	40	27	42	39	78				3.36	− 0.5	13	7,304	s.	32	w.	28	9	4	18	6.5	0.6	0.0				
Greenville	1,070	6		28.93	30.12		43.0		66	11	52	16	30	34	33							4.13		15						11	3	17		T.	0.0				
Portland, Me.	103	82	117	30.03	30.15	+ .15	49.4	+ 2.8	78	10	56	29	30	42	26	45	41	78				3.49	− 0.2	19	5,994	s.	30	w.	28	6	6	19	6.7	0.0	0.0				
Concord	288	70	79	29.82	30.11	+ .10	48.7	− 0.4	78	10	59	24	21	39	35							2.71	− 0.5	17	2,886	n.	27	w.	28	3	8	20	7.5	0.0	0.0				
Burlington	404	11	48	29.65	30.09	+ .05	47.8	+ 0.9	77	10	56	24	30	40	29							6.02	+ 2.9	18	9,160	s.	44	s.	31	2	11	18	7.5	0.0	0.0				
Northfield	876	12	60	29.17	30.13	+ .09	45.3	+ 1.7	76	10	56	20	30	35	35							3.48	+ 1.0		5,982	s.	32	sw.	28	2	11	18	7.9	0.0	0.0				
Boston	125	115	188	30.00	30.14	+ .09	55.1	+ 2.8	81	28	63	33	30	47	32	50	46	77			83	2.13	− 1.7	16	6,264	sw.	38	nw.	28	5	8	18	7.4	0.0	0.0				
Nantucket	12	14	90	30.12	30.12	+ .07	55.0	+ 0.5	77	11	61	39	30	49	21	52	50	85				4.25	+ 0.9	16	11,180	ne.	42	s.	21	8	2	24	7.7	0.0	0.0				
Block Island	26	11	46	30.10	30.13	+ .08	56.2	+ 0.9	76	3	61	41	8	51	22	54	52	89				3.13	− 1.0	13	11,896	ne.	48	nw.	28	6	3	22	7.4	0.0	0.0				
Providence	160	215	251	29.96	30.13	+ .08	54.8	+ 2.6	83	3	63	32	30	46	32	50	46	78				1.49	− 2.4	13	7,800	nw.	48	nw.	28	6	11	14	6.6	0.0	0.0				
Hartford	159	122	140	29.96	30.13	+ .07	55.0	+ 3.2	85	3	64	32	30	46	33	50	47	79				2.95	− 0.9	15	4,523	sw.	34	sw.	28	5	8	18	7.1	0.0	0.0				
New Haven	106	74	153	30.02	30.14	+ .08	56.1	+ 3.3	87	3	64	36	30	48	32	52	48	77				3.62	− 0.3	16	5,936	ne.	31	w.	28	7	9	15	6.2	0.0	0.0				
Middle Atlantic States.							61.2	+ 5.5													82	2.89	− 0.3								6.6							
Albany	97	102	115	30.01	30.12	+ .06	53.6	+ 3.2	82	3	62	31	30	45	31	49	46	79				2.60	− 0.4	13	5,644	s.	30	s.	25	6	12	13	6.3	0.0	0.0				
Binghamton	871	10	84	29.17	30.11	+ .05	54.1	+ 4.9	87	4	64	29	13	44	31							3.40	+ 0.3	15	3,495	nw.	27	sw.	28	2	15	14	7.2	0.0	0.0				
New York	314	414	454	29.79	30.12	+ .06	58.4	+ 2.8	85	3	66	39	13	51	33	54	50	78				3.17	− 0.5	14	10,706	e.	53	w.	28	6	9	16	7.4	0.0	0.0				
Harrisburg	374	94	104	29.75	30.15	+ .07	58.4	+ 4.4	88	3	66	38	13	50	34	53	50	80				2.70	− 0.2	19	3,756	ne.	36	sw.	28	4	8	19	7.1	0.0	0.0				
Philadelphia	117	123	190	30.02	30.15	+ .08	61.2	+ 4.9	90	3	69	41	13	54	32	56	53	81				2.59	− 0.5	15	6,721	n.	30	nw.	28	5	11	15	7.0	0.0	0.0				
Reading	325	81	98	29.79	30.14		58.4		88	3	66	37	13	50	32	54	50	80				2.96	− 0.3	15	3,847	se.	30	nw.	28	7	7	17	7.2	0.0	0.0				
Scranton	805	111	119	29.27	30.14	+ .07	55.6	+ 4.2	85	4	64	32	13	47	32	51	48	82				3.94	+ 1.0	19	4,426	s.	34	sw.	28	8	5	18	6.8	0.0	0.0				
Atlantic City	52	37	48	30.07	30.13	+ .06	61.8	+ 4.4	90	3	68	41	13	56	31	58	56	83				2.11	− 1.2	12	5,629	sw.	20	s.	16	8	11	12	6.2	0.0	0.0				
Cape May	18	13	49	30.14	30.16		63.1	+ 3.5	88	3	69	41	13	57	24	59	57	85				2.92	− 0.4	13	6,009	e.	24	nw.	28	9	9	13	6.2	0.0	0.0				
Sandy Hook	22	10	57	30.11	30.13		59.6		83	3	65	46	13	54	28	56	54	84				2.61		15	10,657	ne.	48	nw.	28	6	12	13	6.5	0.0	0.0				
Trenton	190	159	183	29.92	30.13		58.5		87	3	67	36	13	50	34	55	52	85				3.09	− 0.3	15	7,162	n.	46	w.	28	5	8	18	7.2	0.0	0.0				
Baltimore	123	100	113	30.01	30.14	+ .06	63.0	+ 5.5	92	3	71	41	13	55	31	57	54	78				2.50	− 0.5	10	4,141	se.	24	nw.	28	5	10	16	6.5	0.0	0.0				
Washington	112	62	85	30.01	30.13	+ .05	63.2	+ 6.6	91	3	72	40	13	55	31	57	54	81				3.64	+ 0.6	10	3,740	n.	27	nw.	28	5	9	17	6.8	0.0	0.0				
Lynchburg	681	153	188	29.40	30.14	+ .05	65.4	+ 8.5	94	3	75	38	19	56	33	58	56	79				2.65	− 0.7	13	4,475	w.	23	w.	28	10	8	13	6.2	0.0	0.0				
Norfolk	91	170	205	30.04	30.14	+ .07	70.0	+ 8.7	91	4	77	54	13	63	26	64	61	82				2.27	− 1.6	9	8,506	sw.	43	w.	6	11	14	6	5.1	0.0	0.0				
Richmond	144	11	52	29.99	30.14	+ .06	67.2	+ 7.4	94	3	77	41	20	57	28	60	58	79				1.71	− 1.6	9	5,131	ne.	33	sw.	6	8	8	15	6.2	0.0	0.0				
Wytheville	2,304	49	55	27.77	30.12	+ .04	62.0	+ 8.4	84	2	72	41	18	53	34	57	55	88				3.98	+ 0.8	16	3,429	w.	22	sw.	28	9	8	14	6.2	0 0	0.0				
South Atlantic States.							73.2	+ 9.6													86	2.26	− 1.4								5.5							
Asheville	2,255	70	84	27.82	30.14	+ .05	65.1	+ 9.8	84	5	74	46	18	56	26	60	58	87				1.93	− 1.0	10	4,495	s.	28	se.	21	3	17	11	6.6	0.0	0.0				
Charlotte	779	153	161	29.30	30.13	+ .05	69.9	+ 8.8	93	5	78	48	13	61	26	63	61	83				4.46	+ 1.3	11	3,197	ne.	18	w.	6	3	12	16	6.9	0.0	0.0				
Hatteras	11	12	50	30.11	30.12	+ .06	73.0	+ 7.0	89	6	78	60	18	68	17	69	67	86				2.69	− 3.3	11	8,718	sw.	36	w.	6	11	12	8	4.9	0.0	0.0				
Raleigh	376	103	110	29.73	30.13	+ .06	69.2	+ 8.7	92	5	78	48	13	60	35	63	61	85				2.61	− 0.9	10	4,876	sw.	25	w.	12	7	12	12	6.3	0.0	0.0				
Wilmington	78	81	91	30.05	30.13	+ .07	73.8	+10.5	93	5	82	53	20	66	28	68	66	88				1.03	− 2.7	7	4,658	sw.	20	e.	8	18	8	5	4.0	0.0	0.0				
Charleston	48	11	92	30.07	30.12	+ .06	76.8	+ 9.7	95	6	83	59	19	70	20	71	70	85				0.28	− 3.6	2	6,639	s.	27	e.	8	15	12	4	4.2	0.0	0.0				
Columbia, S. C.	351	41	57	29.76	30.13	+ .06	73.9	+ 9.9	94	5	83	53	20	65	26	66	64	80				3.27	+ 0.4	5	4,333	s.	23	sw.	12	5	15	11	6.0	0.0	0.0				
Greenville, S. C.	1,013	113	122	29.03	30.12		69.2		90	4	77	48	13	62	24	63	61	84				5.50		10	5,567	ne.	27	ne.	13	6	11	14	6.4	0.0	0.0				
Augusta	180	62	77	29.91	30.10	+ .03	74.9	+11.3	94	4	84	55	19	66	26	68	67	86				2.97	+ 0.6	9	3,069	s.	20	s.	17	7	11	13	6.2	0.0	0.0				
Savannah	65	150	194	30.04	30.11	+ .06	77.2	+10.9	94	4	85	58	19	70	21	71	70	89				1.51	− 2.0	9	7,093	se.	42	se.	1	12	10	9	5.2	0 0	0.0				
Jacksonville	43	200	245	30.05	30.10	+ .08	78.6	+ 9.0	90	6	84	65	19	73	17	73	72	88				1.81	− 3.2	7	7,048	e.	32	sw.	1	18	9	4	3.9	0.0	0.0				
Florida Peninsula.							80.7	+ 3.9													77	2.60	− 3.7								4.8							
Key West	22	10	64	29.99	30.01	+ .07	81.6	+ 2.9	89	1	86	70	29	77	14	73	72	77				2.66	− 2.7	13	8,509	e.	32	e.	16	16	9	6	4.3	0.0	0.0				
Miami	25	71	79	30.03	30.06		80.1	+ 2.3	87	2	84	70	28	76	13	75	72	76				3.73	− 6.8	15	7,432	e.	34	e.	15	12	12	7	4.8	0.0	0.0				
Sand Key	23	39	72	29.96	29.99	+ .05	79.7		84	1	82	71	15	77	10	75	73	77							13,025	e.	43			29	13	10	8	4.8	0.0	0.0				
Tampa	35	79	92	30.03	30.06	+ .08	80.4	+ 6.6	93	2	89	68	27	72	23	72	70	79				1.41	− 1.6	7	4,479	e.	24	ne.	28	9	18	4	5.3	0.0	0.0				
East Gulf States.							75.5	+ 9.3													85	4.64	+ 1.8								6.0							
Atlanta	1,174	190	216	28.90	30.12	+ .05	70.8	+ 8.4	88	5	78	50	14	63	24	65	64	85				5.04	+ 2.7	12	6,625	se.	28	s.	16	4	6	21	7.4	0.0	0.0				
Macon	370	78	87	29.71	30.10	+ .04	74.4	+10.7	92	5	84	55	19	65	28	68	66	83				2.82	+ 0.7	6	3,282	s.	22	se.	17	5	14	12	6.4	0.0	0.0				
Thomasville	273	49	58	29.79	30.08	+ .04	78.5	+10.3	94	5	88	60	20	69	25	70	68	81				0.43	− 3.0	5	2,471	e.	15	sw.	23	10	14	7	5.2	0.0	0.0				
Pensacola	56	140	182	30.00	30.06	+ .03	77.4	+10.7	85	1	82	61	18	72	22	73	72	86				8.73	+ 4.6	10	8,218	s.	50	se.	29	7	15	9	5.7	0.0	0.0				
Anniston	741	9	57	29.32	30.11	+ .01	73.6	+11.2	90	4	83	55	1	64	34							4.25	+ 1.9	14	3,426	se.	15	e.	8	6	15	10	5.6	0.0	0.0				
Birmingham	700	11	48	29.34	30.09	− .02	74.5	+10.1	94	1	83	54	18	66	32	67	64	82				2.31	0.0	12	4,545	s.	24	se.	30	5	13	13	6.7	0.0	0.0				
Mobile	57	125	161	29.99	30.05	+ .01	77.5	+10.4	91	1	84	61	18	71	24	72	71	86				8.53	+ 5.4	8	6,482	s.	34	e.	23	12	11	8	5.2	0.0	0.0				
Montgomery	223	100	112	29.84	30.08	+ .02	76.7	+11.0	91	15	85	60	19	68	25	69	67	81				3.61	+ 1.2	9	3,878	se.	35	sw.	4	8	15	8	5.5	0.0	0.0				
Corinth	469	6					70.0		95	1	79	46	19	61	36							7.10		14		s.				3	17	11							
Jackson	304	5					75.4		97	1	86	52	19	65	39							7.16		16		se.				7	14	10							
Meridian	375	85	93	29.66	30.05	− .01	74.4	+11.4	92	2	83	55	18	66	30	68	67	87				2.81	+ 0.1	8	3,220	se.	16	nw.	23	7	15	9	6.0	0.0	0.0				
Vicksburg	247	65	74	29.76	30.04	− .02	73.1	+ 7.8	90	1	81	50	19	65	27	68	67	90				8.29	+ 5.5	17	4,368	se.	20	sw.	22	4	11	16	6.9	0.0	0.0				
New Orleans	53	76	84	29.97	30.02	− .01	79.5	+10.0	90	1	86	65	18	72	21	73	72	88				4.21	+ 1.3	13	4,092	s.	23	se.	3	7	15	9	5.6	0.0	0.0				
West Gulf States.							71.1	+ 4.5													88	9.25	+ 6.5								7.2							
Shreveport	249	77	93	29.75	30.01	− .04	71.4	+ 5.8	89	1	78	50	18	64	24	67	66	89				11.75	+ 8.6	15	4,937	se.	20	se.	22	7	6	18	6.6	0.0	0.0				
Bentonville	1,303	11	44	28.64	30.01	− .04	62.0	+ 4.0	85	1	72	37	28	52	39							10.71	+ 7.9	15	3,785	s.	21	s.	9	6	3	22	7.6	0.0	0.0				
Fort Smith	457	79	94	29.52	29.99	− .06	65.7	+ 4.0	89	1	74	43	28	57	34	61	59	85				7.38	+ 4.6	13	5,317	e.	26	sw.	27	5	4	22	7.6	0.0	0.0				
Little Rock	357	139	147	29.65	30.03	− .03	66.6	+ 3.7	87	1	73	47	28	60	25	62	61	87				15.29	+12.7	17	5,543	s.	40	w.	8	3	7	21	7.8	0.0	0.0				
Brownsville	57	4	26				80.2		94	4	88	63	12	72	23							4.52		15		se.													
Corpus Christi	20	69	77	29.93	29.95	− .05	77.2	+ 4.6	88	8	82	60	17	73	18	73	72	88				3.98	+ 1.9	13	9,527	se.	56	n.	16	1	16	14	6.9	0.0	0.0				
Dallas	512	109	117	29.43	29.97		68.7		86	3	76	47	28	61	33							10.94		15	6,326	s.	29	s.	9	13	11	17	7.2	0.0	0.0				
Fort Worth	670	106	114	29.25	29.95	− .08	68.4	+ 2.1	87	3	77	45	28	60	36	64	63	87				9.44	+ 6.9	12	7,170	s.	28	sw.	26	2	12	17	7.4	0.0	0.0				
Galveston	54	106	114	29.94	30.00	− .03	77.6	+ 5.2	85	9	82	62	18	74	14	73	72	86				8.30	+ 4.1	10	8,464	se.	31	se.	10	9	11	11	5.7	0.0	0.0				
Houston	138	111	121	29.83	29.98		76.0	+ 6.1	88	31	83	59	18	69	22							9.72		13	5,551	se.	33	s.	10	2	13	16	7.2	0.0	0.0				
Palestine	510	64	72	29.46	29.99	− .04	71.6	+ 5.4	87	9	78	52	18	65	21	67	66	89				8.32	+ 4.7	14	4,995	s.	30	nw.	22	4	11	16	7.3	0.0	0.2				
Port Arthur	34	58	66	29.94	29.98		76.6		86	1	82	59	18	71	21	73	72	90				6.49		15	6,293	s.	30	s.	10	4	16	11	6.6	0.0	0.0				
San Antonio	701	119	132	29.23	29.95	− .06	73.8	+ 4.6	90	3	81	53	29	67	25	69	68	90				8.66	+ 7.2	13	5,565	s.	32	n.	16	0	14	17	7.5	0.0	0.0				
Taylor	582	55	63	29.38	29.99	− .03	71.9	+ 3.6	91	4	79	49	29	64	24							8.71	+ 6.2	14	5,842	s.	30	nw.	16	1	12	18	8.2	0.0	0.0				

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.										
																									Miles per hour.	Direction.	Date.							
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	*°F.*		°*F.*	° *F.*		°*F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
							63.9	+ 7.4												82	7.19	+ 4.6										7.1		
Chattanooga	762	180	218	29.31	30.12	+ .03	69.6	+ 8.8	90	1	77	54	19	63	32	64	62	82	6.12	+ 3.3	16	4,757	se.	42	w.	16	3	11	17	7.3	0.0	0.0
Knoxville	996	102	111	29.06	30.11	+ .02	68.9	+10.8	89	4	77	54	21	61	30	63	61	85	5.51	+ 2.9	14	3,762	sw.	24	sw.	5	3	12	16	7.5	0.0	0.0
Memphis	399	76	97	29.66	30.08	− .01	68.0	+ 5.5	89	2	74	46	18	61	26	63	61	86	10.13	+ 7.4	18	5,338	s.	24	sw.	9	4	8	19	7.4	0.0	0.0
Nashville	546	168	191	29.51	30.09	+ .01	68.2	+ 7.9	91	2	75	46	19	61	26	63	61	83	8.35	+ 5.9	16	5,841	s.	32	s.	9	6	8	17	6.9	0.0	0.0
Lexington	989	193	230	29.03	30.09	+ .01	64.0	+ 7.5	89	2	72	42	18	56	25	.....	.....	.....	7.95	+ 5.7	18	8,972	sw.	38	sw.	9	4	7	20	7.3	0.0	0.0
Louisville	525	219	255	29.51	30.09	+ .01	64.6	+ 6.2	91	1	73	43	18	56	27	60	58	86	6.89	+ 4.3	14	7,747	s.	44	w.	31	7	6	18	6.6	0.0	0.0
Evansville	431	139	175	29.61	30.08	.00	64.2	+ 6.2	93	1	72	42	18	56	28	58	56	80	8.30	+ 5.3	14	7,364	sw.	41	w.	9	7	8	16	6.7	0.0	0.0
Indianapolis	822	194	230	29.19	30.07	.00	60.4	+ 5.4	88	1	69	38	28	52	27	55	52	81	8.98	+ 6.2	14	7,950	s.	44	w.	28	7	10	14	6.4	0.0	0.0
Terre Haut	575	96	129	29.44	30.05	.....	60.1	.....	90	1	68	38	18	52	27	55	52	70	8.85	.....	13	6,476	s.	28	w.	28	7	10	14	6.4	0.0	0.0
Cincinnatite	628	11	51	29.41	30.09	+ .01	61.8	+ 8.8	90	2	71	37	29	53	33	57	54	83	9.51	+ 7.2	15	4,718	s.	30	sw.	9	5	10	16	6.9	0.0	0.0
Columbus	824	179	222	29.22	30.09	+ .01	60.4	+ 6.3	88	2	69	38	28	52	31	55	52	81	5.33	+ 3.0	16	7,602	s.	50	nw.	28	6	6	19	7.2	0.0	0.0
Dayton	899	181	216	29.10	30.06	.....	60.8	+ 6.7	89	2	70	38	28	52	32	56	53	83	7.08	+ 4.7	16	6,886	sw.	37	w.	28	4	10	17	7.3	0.0	0.0
Pittsburgh	842	353	410	29.20	30.11	+ .03	60.6	+ 5.7	86	2	68	39	13	53	28	56	53	78	5.37	+ 3.0	18	7,005	sw.	42	nw.	28	8	1	22	7.2	0.0	0.0
Elkins	1,947	41	50	28.09	30.13	+ .03	60.3	+ 8.8	85	2	70	34	19	50	31	54	53	86	5.59	+ 3.3	20	3,327	nw.	26	s.	9	3	5	23	8.3	0.0	0.0
Parkersburg	638	77	82	29.46	30.12	+ .04	63.4	+ 8.8	91		72	39	13	54	28	58	55	82	5.37	+ 2.9	17	3,399	se.		w.	28	4	10	17	7.0	0.0	0.0
Lower Lake Region.							56.3	+ 4.0												79	4.20	+ 1.2										6.5		
Buffalo	767	247	280	29.24	30.08	+ .03	55.2	+ 3.7	76	2	62	37	29	48	25	50	47	78	5.32	+ 1.8	14	12,444	sw.	78	w.	28	5	9	17	7.3	0.0	0.0
Canton	448	10	61	29.59	30.06	.....	47.5	.....	73	10	56	25	8	39	30	.....	.....	.....	3.81	+ 0.5	17	7,216	sw.	60	w.	28	8	6	17	6.7	0.0	0.0
Oswego	335	76	91	29.71	30.08	+ .03	52.9	+ 1.7	79	2	60	34	30	45	26	49	46	....	3.99	+ 0.6	15	7,628	s.	40	w.	28	8	4	18	....	0.0	0.0
Rochester	523	97	113	29.52	30.10	+ .05	54.6	+ 3.8	84	2	62	34	8	47	31	50	46	77	5.05	+ 2.6	16	5,791	sw.	30	w.	28	8	5	18	5.7	0.0	0.0
Syracuse	597	97	113	29.45	30.10	+ .04	53.8	+ 2.8	83	4	62	32	8	46	26	.....	.....	.....	3.69	+ 0.5	16	8,151	s.	54	w.	28	3	11	17	7.1	0.0	0.0
Erie	714	130	166	29.30	30.07	+ .02	57.7	+ 4.6	84	2	65	38	8	51	25	52	49	76	3.04	− 0.8	14	10,196	sw.	50	w.	28	5	7	19	7.0	0.0	0.0
Cleveland	762	190	201	29.26	30.08	+ .02	58.8	+ 5.7	86	3	66	38	29	52	25	54	50	77	3.17	+ 0.4	12	9,203	sw.	56	w.	28	6	12	13	6.5	0.0	0.0
Sandusky	629	62	103	29.39	30.07	+ .01	58.8	+ 4.9	87	3	66	36	29	51	24	.....	.....	.....	4.16	+ 1.7	14	8,151	sw.	42	w.	28	5	11	15	6.2	0.0	0.0
Toledo	628	208	243	29.39	30.08	+ .03	57.4	+ 4.8	86	3	66	36	29	49	26	52	49	79	4.35	+ 2.1	15	9,470	sw.	48	sw.	9	12	6	13	5.4	0.0	0.0
Fort Wayne	856	113	124	29.15	30.08	.....	57.2	+ 3.5	87	3	66	32	29	48	30	52	49	81	5.05	.....	14	6,005	sw.	40	sw.	9	8	8	15	6.2	0.0	0.0
Detroit	730	218	245	29.28	30.08	+ .03	56.4	+ 4.7	84	3	64	38	17	49	22	52	49	82	4.28	+ 2.6	13	7,769	sw.	40	w.	28	13	2	16	5.9	0.0	0.0
Upper Lake Region.							49.1	+ 1.5												80	3.70	+ 0.9										6.6		
Alpena	609	13	92	29.38	30.05	+ .02	48.7	+ 2.8	78	2	56	31	12	41	29	45	42	80	2.73	− 0.7	16	8,237	nw.	60	nw.	28	4	2	25	7.8	T.	0.0
Escanaba	612	54	60	29.36	30.04	+ .03	45.6	+ 0.5	74	6	53	24	29	38	31	42	38	81	4.70	+ 1.6	15	7,065	s.	35	ne.	6	11	7	13	5.4	0.3	0.0
Grand Haven	632	54	89	29.35	30.04	+ .01	52.6	+ 2.4	83	3	60	34	20	45	29	49	46	81	4.39	+ 1.9	16	7,813	s.	49	nw.	3	7	8	16	6.7	0.0	0.0
Grand Rapids	707	70	87	29.28	30.05	+ .01	54.6	+ 4.5	85	3	64	34	20	46	28	49	46	77	3.91	+ 1.4	16	4,153	se.	31	w.	28	5	10	16	7.0	0.0	0.0
Houghton	684	62	99	29.28	30.01	+ .01	42.0	− 3.1	74	8	49	25	29	35	38	.....	.....	.....	3.02	− 0.2	16	7,366	w.	48	sw.	6	5	5	21	7.8	7.1	0.0
Lansing	878	11	62	29.11	30.06	.....	53.3	+ 4.6	84	2	64	28	20	43	28	48	46	85	2.90	+ 0.7	17	4,155	sw.	24	se.	27	6	12	13	6.1	0.0	0.0
Ludington	637	60	66	29.33	30.03	.....	50.4	.....	70	2	57	30	20	44	31	47	44	80	3.17	.....	17	7,899	se.	42	w.	28	6	8	17	6.6	0.0	0.0
Marquette	734	77	111	29.23	30.04	+ .03	45.0	− 0.7	80	2	53	24	29	37	34	40	36	76	3.26	+ 0.1	16	6,342	sw.	39	sw.	8	3	8	20	7.6	2.9	0.0
Port Huron	638	70	120	29.37	30.06	+ .02	54.4	+ 5.9	85	2	63	33	18	46	31	49	46	80	2.68	0.0	11	7,151	sw.	44	nw.	28	8	10	13	5.8	0.0	0.0
Saginaw	641	69	77	29.36	30.06	.....	52.8	.....	84	2	62	31	20	44	28	48	45	82	3.53	+ 0.7	16	6,030	sw.	32	nw.	28	6	10	15	6.4	T.	0.0
Sault Sainte Marie	614	11	52	29.34	30.04	+ .03	44.5	+ 1.1	74	3	52	27	28	37	30	42	39	84	4.83	+ 1.6	19	6,173	se.	37	w.	28	6	10	15	6.4	T.	0.0
Chicago	823	140	310	29.16	30.05	+ .01	57.2	+ 4.0	85	2	65	35	29	50	29	52	48	73	6.41	+ 3.9	14	8,757	w.	42	sw.	9	11	9	11	5.5	0.0	0.0
Green Bay	617	109	144	29.35	30.02	.00	48.4	+ 1.3	75	2	56	24	29	40	27	44	40	79	2.36	0.0	12	8,459	s.	40	nw.	6	0	10	21	8.4	1.4	0.0
Milwaukee	681	119	133	29.29	30.03	.00	52.2	+ 2.0	82	2	60	29	29	45	31	48	44	78	3.92	+ 1.5	13	7,425	sw.	36	sw.	9	8	12	11	6.0	0.0	0.0
Duluth	1,133	11	47	28.78	30.02	+ .01	39.4	− 5.8	73	8	47	18	26	32	34	35	31	78	2.71	0.0	12	9,541	w.	44	ne.	1	11	4	16	5.9	6.0	T.
North Dakota.							33.7	− 8.8												74	1.12	− 0.1										3.5		
Moorhead	940	8	57	29.02	30.07	+ .07	36.5	− 6.3	79	8	47	− 4	26	26	36	32	28	80	1.22	− 0.8	9	5,857	n.	27	s.	8	15	4	12	4.8	4.1	0.5
Bismarck	1,674	8	57	28.26	30.09	+ .10	34.6	− 9.5	83	8	46	−10	26	23	41	30	25	76	0.98	0.0	7	6,018	nw.	30	nw.	9	10	10	11	5.6	11.4	5.2
Devils Lake	1,482	11	44	28.42	30.04	+ .05	31.8	− 8.7	80	8	43	− 1	25	21	38	27	22	74	0.65	− 0.6	9	7,065	w.	32	n.	22	10	8	13	5.7	6.4	3.8
Ellendale	1,457	10	56	28.46	30.05	.....	36.0	.....	78	1	47	− 4	28	24	39	31	27	77	1.50	.....	11	9,162	nw.	41	s.	8	8	7	16	6.6	12.4	0.2
Grand Forks	835	12	89	.....	.....	.....	32.8	.....	80	1	44	− 9	21	26	....	36	29	....	0.82	.....	8	.....	w.	33	sw.	8	11	9	11	....	5.0	3.0
Williston	1,878	41	48	28.02	30.05	+ .07	32.1	−10.8	76	7	43	− 2	26	21	44	27	21	67	1.65	+ 0.9	11	5,856	sw.	36	nw.	22	8	11	12	5.9	11.0	8.7
Upper Mississippi Valley.							54.0	+ 1.2												81	4.20	+ 1.9										6.3		
Minneapolis	918	10	208	29.00	30.00	.....	44.7	.....	77	2	53	19	28	37	30	.....	.....	.....	1.69	− 0.9	11	8,453	nw.	34	se.	1	5	10	16	7.1	2.6	0.0
St. Paul	837	236	261	29.10	30.02	+ .01	44.2	− 3.9	77	2	52	19	28	36	32	.....	.....	.....	1.91	− 0.4	11	8,773	se.	34	s.	8	4	10	17	7.1	2.5	0.0
La Crosse	714	11	48	29.24	30.02	.00	48.2	− 1.7	83	2	57	25	29	40	33	.....	.....	.....	3.20	+ 0.7	13	3,460	se.	17	sw.	20	5	5	21	7.3	T.	0.0
Madison	974	70	78	28.99	30.05	+ .02	50.2	+ 1.4	78	2	58	25	29	42	28	46	43	83	5.95	+ 3.5	13	6,458	s.	28	sw.	9	6	6	19	7.2	0.0	0.0
Wausau	1,247	4	.....	28.68	30.03	.....	44.8	.....	81	2	53	22	29	36	30	.....	.....	.....	3.57	.....	14	.....	nw.	.....	.....	.....	12	2	17	5.9	1.1	0.0
Charles City	1,015	10	49	28.94	30.03	+ .01	47.8	− 0.4	84	2	56	19	28	39	30	43	40	80	3.56	+ 1.5	13	4,761	s.	23	nw.	28	7	13	11	6.3	T.	0.0
Davenport	606	71	79	29.37	30.04	.00	54.6	+ 2.0	86	1	64	28	29	45	31	49	46	81	5.32	+ 2.9	13	5,126	e.	25	nw.	28	12	7	12	5.5	0.0	0.0
Des Moines	861	84	97	29.09	30.01	− .02	52.1	− 0.4	86	1	62	22	29	43	30	46	43	78	2.20	− 0.5	11	5,085	s.	37	sw.	1	7	12	12	6.2	0.0	0.0
Dubuque	698	81	96	29.30	30.05	+ .01	52.0	0.0	82	1	61	25	29	43	30	47	44	80	6.22	+ 3.5	14	4,269	s.	26	ne.	4	6	13	12	6.3	0.0	0.0
Keokuk	614	64	78	29.37	30.05	.00	56.5	+ 2.0	87	1	66	29	29	47	34	50	46	76	1.68	+ 0.8	12	5,058	s.	27	se.	24	11	8	12	5.3	0.0	0.0
Cairo	356	87	93	29.67	30.05	− .02	64.7	+ 5.6	88	1	72	44	18	58	31	60	58	85	5.97	+ 3.3	16	5,900	s.	26	sw.	9	4	6	21	7.5	0.0	0.0
Peoria	609	11	45	29.38	30.05	.00	55.8	+ 3.8	88	1	67	26	29	45	32	50	48	87	2.12	− 0.4	12	4,103	s.	22	sw.	9	15	4	12	4.6	0.0	0.0
Springfield, Ill.	644	10	91	29.36	30.04	− .01	57.8	+ 3.2	88	1	67	34	29	48	29	52	50	86	5.63	+ 3.0	13	5,429	s.	24	sw.	9	9	7	15	6.1	0.0	0.0
Hannibal	534	74	109	29.46	30.04	− .01	57.4	+ 1.5	87	1	67	30	29	47	34	.....	.....	.....	4.87	+ 3.2	11	5,514	sw.	27	sw.	9	8	7	16	6.2	0.0	0.0
St. Louis	567	265	303	29.43	30.04	− .02	60.8	+ 2.4	89	1	68	39	28	53	30	55	51	76	8.52	+ 6.1	13	8,864	s.	50	s.	8	6	9	16	6.5	0.0	0.0
Missouri Valley.							50.3	− 2.4												76	3.23	+ 1.3										6.5		
Columbia, Mo.	781	11	84	29.20	30.03	− .02	57.6	+ 2.8	88	2	67	32	28	48	32	.....	.....	.....	7.68	+ 5.3	14	4,920	se.	24	nw.	28	9	6	16	6.1	0.0	0.0
Kansas City	963	161	181	28.97	30.01	− .03	56.6	+ 0.8	90	2	66	28	28	48	36	50	46	72	1.38	− 0.8	11	7,682	s.	30	nw.	9	11	7	13	5.9	0.0	0.0
St. Joseph	967	11	49	28.97	30.01	.....	54.4	.....	89	2	64	24	28	44	38	48	44	76	2.46	.....	12	5,426	se.	30	nw.	24	10	9	12	5.5	0.0	0.0
Springfield, Mo.	1,324	98	104	28.63	30.03	− .02	59.9	+2.6	85	1	69	35	28	51	37	54	51	83	11.94	+ 9.1	15	7,172	s.	30	sw.	9	7	7	17	6.7	0.0	0.0
Iola	984	11	50	28.96	30.00	− .04	57.4	+ 0.5	90	1	67	29	28	47	36	.....	.....	.....	5.33	+ 3.1	14	4,904	s.	22	s.	1	5	9	17	7.2	0.0	0.0
Topeka	987	92	107	.....	.....	.....	55.0	− 1.3	91	2	65	25	28	45	41	.....	.....	.....	1.13	− 0.8	6	7,091	s.	32	sw.	1	10	5	16	6.1	0.0	0.0
Drexel	1,299	10	54	28.58	29.98	.....	48.0	.....	85	1	58	17	28	38	32	43	41	82	1.72	.....	8	6,950	s.	34	sw.	1	10	6	15	5.8	T.	0.0
Lincoln	1,189	11	84	28.73	30.01	− .02	50.2	− 3.1	87	1	59	22	28	41	34	45	41	77	1.41	− 0.4	6	6,725	s.	30	nw.	24	11	6	14	5.8	0.0	0.0
Omaha	1,105	115	122	28.83	30.02	− .01	50.6	− 3.6	87	1	59	19	28	42	36	45	41	75	2.79	+ 0.4	14	5,669	s.	34	nw.	24	10	8	13	5.8	T.	0.0
Valentine	2,598	47	54	27.28	30.04	+ .03	41.8	− 6.7	80	1	53	9	28	31	43	36	31	76	1.20	− 0.1	10	6,984	w.	33	w.	1	12	9	10	5.2	2.3	0.0
Sioux City	1,135	94	164	28.80	30.03	+ .01	46.9	− 4.2	84	1	56	15	28	38	34	42	38	77	1.12	− 0.7	11	8,353	n.	40	nw.	9	6	9	16	6.4	0.2	0.0
Huron	1,306	59	74	28.64	30.06	+ .05	41.4	− 3.3	87	1	52	2	26	31	41	35	31	75	1.08	− 0.3	14	7,207	nw.	35	nw.	9	10	6	15	5.8	2.3	0.0
Pierre	1,572	70	75	28.36	30.06	+ .05	40.8	− 8.3	83	1	52	1	26	30	39	34	29	72	2.19	+ 1.4	9	5,296	nw.	44	w.	30	10	8	13	5.5	9.5	T.
Yankton	1,233	49	57	28.68	30.01	.00	45.8	− 4.7	85	1	55	14	28	36	37	.....	.....	.....	1.50	− 0.1	9	4,283	n.	24	nw.	24	6	10	15	6.7	T.	0.0

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
Northern Slope.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° F.	° F.	°F.		°F.	° F.		°F.	° F.		°F.	°F.	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
							36.7	— 8.1											73	2.13	+ 1.2										5.2		
Billings	3,140	5	....																														
Havre	2,505	11	44	27.36	30.06	+ .08	34.4	— 9.2	79	7	46	— 7	25	23	44		30	27	80	0.75	+ 0.2	9	5,103	sw.	33	sw.	8	9	7	15	6.4	3.3	1.7
Helena	4,110	87	112	25.80	30.07	+ .10	35.7	— 8.3	70	7	45	— 1	24	26	43		31	26	71	1.25	+ 0.4	10	5,413	sw.	28	sw.	27	4	9	18	6.9	15.6	3.8
Kalispell	2,962	11	31	.....	30.05	+ .04	36.4	— 7.1	73	7	46	7	25	26	41		....	....	....	1.05	— 0.1	9	3,489	nw.	29	sw.	8	7	4	20	3.2	6.5	3.0
Miles City	2,371	26	48	27.50	30.12	+ .11	36.9	— 9.6	77	7	47	— 4	26	27	36		31	28	79	2.47	+ 1.7	12	3,954	ne.	27	n.	8	8	13	10	5.4	13.8	2.7
Rapid City	3,259	50	58	25.60	30.10	+ .09	37.5	— 9.1	73	8	48	2	26	27	34		31	26	69	3.26	+ 2.2	12	5,191	n.	38	sw.	1	10	8	13	5.6	15.1	0.8
Cheyenne	6,088	81	101	23.95	29.98	— .03	40.5	— 4.8	68	1	51	19	10	30	31		33	26	65	1.67	+ 1.0	7	9,204	w.	48	w.	30	16	9	6	4.8	7.8	0.0
Lander	5,372	60	68	24.62	30.08	+ .04	33.1	— 9.0	61	8	44	4	25	22	34		28	23	72	4.64	+ 3.6	10	2,883	sw.	34	w.	1	9	9	13	6.0	30.4	T.
Sheridan	3,790	10	47	26.09	30.07	.....	35.7	.....	75	8	47	5	27	24	49		31	27	78	2.87	.....	16	3,475	nw.	38	nw.	30	5	3	23	7.4	10.7	T.
Yellowstone Park	6,200	11	48	23.84	30.07	+ .05	30.4	—11.1	63	7	40	— 6	27	20	37		26	21	72	2.69	+ 1.6	15	5,706	s.	42	s.	8	6	5	20	7.0	26.6	10.8
North Platte	2,821	11	51	27.09	30.05	+ .03	45.3	— 4.7	82	1	57	15	28	33	40		38	33	72	1.36	+ 0.2	8	5,192	n.	29	ne.	3	15	6	10	4.7	0.1	0.0
Middle Slope.							52.9	— 2.6											72	2.13	+ 0.6										5.6		
Denver	5,292	106	113	24.68	29.96	.00	46.4	— 4.6	78	1	58	24	28	35	37		37	28	58	0.65	— 0.3	7	5,166	s.	29	ne.	25	13	10	8	4.8	1.9	0.0
Pueblo	4,685	80	86	25.24	29.93	— .06	49.9	— 2.4	88	1	64	17	28	36	52		39	29	58	0.30	— 0.4	7	4,406	e.	30	e.	9	15	7	9	4.1	T.	0.0
Concordia	1,392	50	58	28.53	30.02	— .01	52.1	— 3.3	91	1	62	23	28	42	31		46	42	76	1.05	— 1.0	7	5,630	s.	26	s.	30	11	6	14	6.0	0.0	0.0
Dodge City	2,509	11	51	27.39	30.00	— .02	53.3	— 1.4	92	1	66	21	28	41	39		45	41	75	1.01	— 0.4	5	7,304	s.	28	ne.	9	13	12	6	4.7	0.0	0.0
Wichita	1,358	139	158	28.56	29.99	— .04	56.2	— 2.6	90	1	66	27	28	47	44		51	47	78	1.64	— 0.7	11	9,441	s.	46	s.	1	8	10	13	6.3	0.0	0.0
Altus	1,410	5	....																														
Muskogee	652	4	....																														
Oklahoma	1,214	10	47	28.72	30.00	— .03	59.7	— 1.6	88	1	68	37	28	51	32		55	54	88	8.12	+ 6.3	16	9,287	s.	38	nw.	15	5	4	22	7.6	0.0	0.0
Southern Slope.							63.8	+ 1.4											76	1.72	— 0.2										6.4		
Abilene	1,738	10	52	28.16	29.96	— .05	65.8	+ 1.6	86	4	75	38	28	57	36		61	59	86	3.99	+ 1.7	13	6,683	s.	28	sw.	8	5	7	19	7.6	0.0	0.0
Amarillo	3,676	10	49	26.24	29.95	— .05	57.8	+ 1.7	86	2	69	34	28	46	39		49	45	74	0.67	— 1.0	8	8,216	s.	30	se.	29	10	14	7	5.0	0.0	0.0
Del Rio	944	64	71	28.92	29.90	— .08	72.2	+ 2.3	86	5	79	48	29	66	25		....	....	....	1.58	— 0.4	16	6,912	se.	32	nw.	28	0	16	15	7.4	0.0	0.0
Roswell	3,566	75	85	26.33	29.91	— .05	59.5	0.0	88	1	71	39	28	48	37		51	45	69	0.62	— 0.9	4	4,873	s.	29	sw.	26	11	7	13	5.5	0.0	0.0
Southern Plateau.							60.0	— 2.9											51	0.64	+ 0.1										2.6		
El Paso	3,762	110	133	26.15	29.87	— .05	65.1	+ 2.7	84	1	74	48	28	56	25		54	46	58	0.97	0.0	5	7,304	nw.	38	ne.	16	12	15	4	4.6	0.0	0.0
Santa Fe	7,013	57	66	23.22	29.92	— .04	47.1	— 2.9	70	1	57	24	28	37	29		38	31	63	1.82	+ 0.8	7	4,872	sw.	30	sw.	26	17	8	6	3.7	T.	0.0
Flagstaff	6,908	8	57	23.31	29.89	.....	42.0	.....	63	11	55	20	21	29	42		35	....	....	3.42	.....	8	.....	w.	36	w.	26	18	9	4	.....	0.0	.....
Phoenix	1,108	76	81	28.72	29.87	— .01	66.7	— 3.5	90	16	81	42	29	53	39		55	48	60	0.25	— 0.1	2	3,125	e.	27	e.	11	22	5	4	2.5	0.0	0.0
Yuma	141	9	54	29.72	29.86	— .01	67.8	— 4.6	93	17	83	40	29	53	42		53	40	43	0.14	0.0	1	3,802	n.	30	n.	31	25	3	3	1.5	0.0	0.0
Independence	3,957	11	42	25.96	30.00	+ .05	53.1	— 6.2	77	17	68	24	25	38	39		38	20	31	T.	— 0.3	0	4,494	nw.	26	se.	24	28	3	0	0.7	0.0	0.0
Needles	488	4	....	29.38	29.90	.....	64.5	.....	88	11	78	36	30	52	39		....	....	....	0.13	.....	2	.....	....	....	....	....	22	1	8	1.6	0.0	0.0
Middle Plateau.							44.4	— 6.1											54	0.86											3.4		
Reno	4,532	74	81	25.49	30.05	+ .06	45.0	— 4.7	74	16	60	18	31	30	41		37	29	58	0.24	— 0.2	2	4,375	w.	32	w.	23	21	9	1	2.2	1.4	0.0
Tonopah	6,090	12	20	24.06	30.00	.....	43.8	.....	68	17	54	19	27	34	32		33	20	41	0.32	— 0.5	1	5,754	w.	44	nw.	29	25	6	0	1.8	2.5	0.0
Winnemucca	4,344	18	56	25.65	30.09	+ .04	42.0	— 6.6	72	16	56	14	31	27	47		34	26	62	0.68	+ 0.2	7	4,146	ne.	30	nw.	17	16	8	7	3.8	5.0	0.0
Modena	5,479	10	43	24.60	29.98	+ .02	42.2	— 7.9	67	16	56	17	20	28	42		33	22	52	0.63	— 0.2	4	7,842	sw.	43	s.	24	20	8	3	2.8	0.1	0.0
Salt Lake City	4,360	163	203	25.63	30.03	+ .02	44.6	— 7.6	70	17	53	23	28	36	32		37	30	62	2.52	+ 1.1	13	4,774	se.	39	nw.	23	9	9	13	5.8	10.6	T.
Grand Junction	4,602	82	96	25.36	29.95	— .04	48.4	— 3.9	73	2	60	24	28	36	37		38	28	51	0.76	— 0.2	7	4,068	se.	29	s.	18	14	10	7	4.2	4.5	0.0
Northern Plateau.							44.8	— 4.6											64	1.20	0.0										5.8		
Baker	3,471	48	53	26.48	30.11	+ .03	40.0	— 5.5	73	7	52	12	27	28	37		35	29	68	0.77	— 0.1	9	4,232	se.	25	sw.	8	10	10	11	5.4	2.0	0.8
Boise	2,739	78	86	27.21	30.10	+ .04	44.9	— 5.4	70	7	56	19	27	34	32		38	31	62	1.41	+ 0.1	9	3,091	nw.	31	nw.	8	13	8	10	4.7	2.6	0.2
Lewiston	757	40	48	29.26	30.08	— .01	48.6	— 3.2	80	7	60	24	25	38	37		....	....	....	1.12	— 0.1	11	2,254	e.	26	nw.	8	7	7	17	6.7	1.0	0.0
Pocatello	4,477	60	68	25.47	30.04	.00	41.8	— 6.2	65	8	50	19	31	33	30		35	29	66	1.26	+ 0.3	10	6,876	se.	52	sw.	8	7	8	16	6.2	3.8	0.0
Spokane	1,929	101	110	28.01	30.09	+ .03	43.4	— 3.9	76	7	54	12	25	32	37		37	30	63	0.69	— 0.8	11	2,942	sw.	23	sw.	7	7	11	13	6.2	2.1	0.5
Walla Walla	991	57	65	29.01	30.09	+ .02	50.2	— 3.5	82	7	59	25	25	41	30		43	36	60	1.95	+ 0.5	8	3,652	s.	32	nw.	8	11	11	9	5.3	1.8	0.0
North Pacific Coast Region.							49.0	— 2.8											83	2.10	— 1.8										6.6		
North Head	211	11	56	29.92	30.15	+ .10	49.3	— 3.6	72	6	53	36	25	45	18		47	45	88	2.38	— 1.5	18	8,942	nw.	60	s.	31	6	13	12	5.9	0.0	0.0
North Yakima	1,071	4	....																														
Port Angeles	29	8	48	30.13	30.16	.....	45.9	.....	62	21	53	27	25	39	19		....	....	....	1.72	— 0.8	12	4,192	s.	34	w.	7	6	6	19	7.0	0.1	0.0
Seattle	125	215	250	30.02	30.15	+ .10	48.5	— 2.3	67	6	54	29	25	43	21		46	43	82	1.59	— 1.3	15	5,185	n.	38	sw.	27	1	11	19	7.8	0.0	0.0
Tacoma	213	113	120	29.92	30.15	+ .11	48.6	— 2.0	70	7	54	29	25	43	25		46	44	84	1.85	— 1.6	11	4,000	n.	26	sw.	21	2	8	21	8.0	0.0	0.0
Tatoosh Island	86	7	57	30.02	30.12	+ .11	47.0	— 2.9	64	6	50	37	25	44	16		45	44	89	3.46	— 4.5	13	8,245	s.	49	w.	8	8	9	14	5.8	0.0	0.0
Medford	1,425	4	....																														
Portland, Oreg.	153	68	106	29.97	30.13	+ .07	50.9	— 2.4	78	6	58	30	27	44	27		47	44	77	1.43	— 2.3	10	3,525	nw.	23	sw.	31	6	7	18	6.9	0.0	0.0
Roseburg	510	9	57	29.61	30.17	+ .09	49.4	— 3.5	77	6	59	32	25	40	33		46	42	79	2.28	— 0.3	10	1,630	nw.	17	sw.	22	11	12	8	4.9	0.0	0.0
Middle Pacific Coast Region.							57.6	— 0.8											62	0.42	— 1.0										2.3		
Eureka	62	73	89	30.04	30.11	+ .05	50.6	— 2.5	73	6	58	35	27	44	26		47	45	83	0.24	— 2.4	6	4,390	n.	34	n.	17	18	9	4	3.4	0.0	0.0
Mount Tamalpais	2,375	11	31	.....	30.01	.00	57.6	— 1.1	78	12	64	37	25	51	19		....	....	....	1.35	+ 0.1	....	12,613	nw.	78	nw.	29	24	5	2	....	0.0	0.0
Point Reyes Light	490	7	18	29.46	29.97	.....	54.7	0.0	75	5	60	45	9	49	19		....	....	....	0.44	.....	3	13,565	nw.	73	nw.	29	17	8	6	3.3	0.0	0.0
Red Bluff	332	50	56	29.64	29.99	— .01	61.6	— 2.2	91	12	75	38	26	48	39		49	34	42	0.36	— 1.2	2	4,778	nw.	33	nw.	8	25	3	3	1.5	0.0	0.0
Sacramento	69	106	117	29.91	29.98	— .01	60.6	— 1.6	86	11	74	39	29	47	37		51	41	53	0.01	— 1.0	1	5,988	nw.	32	nw.	9	25	6	0	1.3	0.0	0.0
San Francisco	155	208	243	29.83	30.00	— .01	60.7	+ 2.3	83	6	70	48	16	52	27		52	46	69	0.27	— 1.0	2	6,559	sw.	32	w.	16	23	4	4	2.5	0.0	0.0
San Jose	141	12	110	29.86	30.01	.....	58.2	.....	86	12	74	35	30	43	41		....	....	....	0.28	— 0.6	1	4,081	nw.	24	nw.	29	24	4	3	2.0	0.0	0.0
South Pacific Coast Region.							62.0	— 0.8											62	0.50	— 0.3										2.0		
Fresno	327	89	98	29.62	29.98	+ .02	62.0	— 2.7	87	13	75	37	31	49	34		49	36	43	0.29	— 0.4	2	4,111	nw.	27	nw.	29	27	3	1	0.9	0.0	0.0
Los Angeles	338	159	191	29.59	29.96	+ .01	63.8	— 0.8	88	16	73	47	27	54	32		55	49	68	0.56	— 0.2	2	4,074	sw.	18	sw.	24	23	5	3	2.4	0.0	0.0
San Diego	87	62	70	29.85	29.94	— .01	62.0	— 1.0	83	17	69	46	29	55	24		56	52	74	1.04	+ 0.6	3	4,103	nw.	26	se.	24	20	8	3	3.1	0.0	0.0
San Luis Obispo	201	32	40	29.77	29.99	.00	60.4	+ 1.2	92	16	75	35	26	46	46		49	41	62	0.12	— 1.2	1	2,804	nw.	18	nw.	3	25	4	2	1.6	0.0	0.0
West Indies.																																	
San Juan, P. R.	82	8	54	29.87	29.95	.....	79.4	.....	89	14	84	70	11	74	15		....	....	....	5.78	—0.2	24	8,362	ne.	44	ne.	30	4	26	1	4.7	0.0	0.0
Panama Canal.																																	
Balboa Heights	118	7	97	29.71	29.83	— .01	79.7	+ 0.5	90	21	86	70	6	74	18		75	74	87	12.11	+1.78	22	4,516	nw.	31	s.	24	1	11	19	7.6	0.0	0.0
Colon	36	15	97	29.79	29.83	— .02	80.1	+ 0.7	90	29	85	71	4	75	16		76	75	84	21.94	+6.91	26	5,822	se.	30	w.	22	1	12	18	8.0	0.0	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during October, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	21			1.02														0.68			
Albany, N. Y.	4			0.79														0.46			
Alpena, Mich.	30			0.39														0.18			
Amarillo, Tex.	5			0.25														0.13			
Anniston, Ala.	22			1.20														0.72			
Asheville, N. C.	22			1.03														0.36			
Atlanta, Ga.	8	1:05 p. m.	3:35 p. m.	2.34	2:30 p. m.	3:29 p. m.	0.22	0.14	0.32	0.40	0.44	0.46	0.61	0.98	1.34	1.51	1.71	2.11			
Atlantic City, N. J.	11			0.46														0.25			
Augusta, Ga.	17	6:30 p. m.	10:00 p. m.	1.22	7:13 p. m.	7:53 p. m.	0.01	0.13	0.29	0.37	0.50	0.62	0.67	0.81	0.94						
	23	1:00 p. m.	1:45 p. m.	0.66	1:18 p. m.	1:42 p. m.	0.02	0.07	0.15	0.34	0.51	0.64									
Baker, Oreg.	22–23			0.28														(*)			
Baltimore, Md.	1			0.29														0.20			
Bentonville, Ark.	8	8:30 a. m.	7:20 p. m.	3.64	5:30 p. m.	6:27 p. m.	1.24	0.24	0.48	0.70	0.95	1.28	1.55	1.85	2.13	2.18	2.21	2.31			
	30–31	10:10 p. m.	1:00 a. m.	1.16	11:25 p. m.	11:55 p. m.	0.16	0.06	0.11	0.28	0.49	0.76	0.96								
Binghamton, N. Y.	31			0.78														0.40			
Birmingham, Ala.	8			0.58														0.52			
Bismarck, N. Dak.	23–24			0.39														(*)			
Block Island, R. I.	11			0.39														0.32			
Boise, Idaho.	28–29			0.68														(*)			
Boston, Mass.	16			0.35														0.25			
Buffalo, N. Y.	6			0.54														0.50			
Burlington, Vt.	10			0.52														0.50			
Cairo, Ill.	8–9	D. N. p. m.	5:43 a. m.	1.40	12:06 a. m.	12:46 a. m.	0.10	0.15	0.17	0.19	0.23	0.29	0.39	0.65	0.78						
Canton, N. Y.	5			0.71														0.51			
Charles City, Iowa.	3–4	9:25 p. m.	3:45 a. m.	1.24	11:57 p. m.	12:12 a. m.	0.24	0.25	0.62	0.75											
Charleston, S. C.	22			0.20														0.20			
Charlotte, N. C.	21–22	11:40 p. m.	3:00 a. m.	1.07	12:45 a. m.	1:38 a. m.	0.07	0.20	0.39	0.45	0.48	0.48	0.50	0.60	0.61	0.69	0.80	0.90			
Chattanooga, Tenn.	16	2:24 p. m.	3:25 p. m.	0.95	2:25 p. m.	2:55 p. m.	[1] T.	[1]0.08	[1]0.28	[1]0.45	[1]0.61	[1]0.74	[1]0.90								
Cheyenne, Wyo.	3–4			0.64														(*)			
Chicago, Ill.	5	8:02 a. m.	10:30 a. m.	1.71	8:13 a. m.	8:48 a. m.	0.03	0.09	0.28	0.61	1.02	1.19	1.38	1.53							
	9–10	11:00 p. m.	1:10 a. m.	1.26	11:37 p. m.	12:44 a. m.	0.14	0.06	0.17	0.22	0.30	0.38	0.49	0.56	0.61	0.71	0.80	0.98	1.10		
Cincinnati, Ohio.	5	3:50 p. m.	6:30 p. m.	0.87	5:03 p. m.	5:21 p. m.	0.19	0.12	0.33	0.52	0.61										
	26	D. N. a. m.	6:10 a. m.	0.64	4:09 a. m.	4:23 a. m.	0.09	0.16	0.44	0.53											
Cleveland, Ohio.	31			0.41														0.26			
Columbia, Mo.	4			0.73														0.61			
Columbia, S. C.	23–24	5:45 p. m.	D. N. a. m.	1.57	9:12 p. m.	9:23 p. m.	0.98	0.34	0.52	0.54											
Columbus, Ohio.	16			0.80														0.43			
Concord, N. H.	28			0.67														0.30			
Concordia, Kans.	8			0.46														0.22			
Corpus Christi, Tex.	28–29	11:33 p. m.	D. N. a. m.	0.70	12:11 a. m.	12:36 a. m.	0.12	0.13	0.26	0.40	0.48	0.54									
Dallas, Tex.	10–11	2:16 p. m.	6:20 a. m.	1.52	2:25 p. m.	2:42 p. m.	0.01	0.16	0.35	0.48	0.53										
	16	4:32 a. m.	6:15 a. m.	1.09	4:34 a. m.	9:35 a. m.	0.01	0.25	0.30	0.31	0.47	0.49	0.51	0.55	0.63	0.71	0.79	0.99	1.04		
	21	7:15 p. m.	11:55 p. m.	1.50	8:35 p. m.	9:25 p. m.	0.10	0.12	0.22	0.34	0.38	0.40	0.50	0.66	0.88	0.98	1.05				
	31–1	8:06 p. m.	12:20 a. m.	3.42	8:39 p. m.	9:29 p. m.		0.08	0.16	0.36	0.61	0.76	0.82	0.87	0.93	1.03	1.08				
					9:29 p. m.	10:19 p. m.		1.15	1.28	1.42	1.64	1.91	2.11	2.16	2.41	2.55	2.69				
					10:19 p. m.	11:05 p. m.	0.08	2.76	2.76	2.77	2.78	2.78	2.83	3.02	3.15	3.21	3.24				
Davenport, Iowa.	4	4:47 p. m.	8:15 p. m.	2.02	5:00 p. m.	5:59 p. m.	0.10	0.17	0.56	0.83	0.98	1.02	1.06	1.11	1.25	1.38	1.48	1.61			
Dayton, Ohio.	27			1.54														0.35			
Del Rio, Tex.	16			0.40														0.26			
Denver, Colo.	3–4			0.36														(*)			
Des Moines, Iowa.	4			0.53														0.46			
Detroit, Mich.	5	1:20 p. m.	3:10 p. m.	1.46	1:34 p. m.	2:12 p. m.	0.01	0.40	0.75	0.90	0.99	1.08	1.15	1.29	1.39						
Devils Lake, N. Dak.	30			0.22														(*)			
Dodge City, Kans.	13			0.42														0.24			
Drexel, Nebr.	19			0.56														0.36			
Dubuque, Iowa.	4	3:05 p. m.	5:30 p. m.	3.06	3:18 p. m.	4:38 p. m.	0.04	0.15	0.35	0.70	1.27	1.63	1.98	2.18	2.33	2.44	2.54	2.66	2.97		
Duluth, Minn.	24			0.91														0.36			
Eastport, Me.	6			0.56														(*)			
Elkins, W. Va.	14			1.12														0.30			
Ellendale, N. Dak.	19–20			0.51														(*)			
El Paso, Tex.	11			0.39														0.31			
Erie, Pa.	31			0.71														0.22			
Escanaba, Mich.	1			0.88														0.50			
Eureka, Calif.	22			0.04														0.04			
Evansville, Ind.	21	2:00 a. m.	9:35 a. m.	1.09	3:28 a. m.	3:50 a. m.	0.16	0.11	0.31	0.50	0.58	0.62									
Flagstaff, Ariz.																					
Fort Smith, Ark.	20–21	9:30 p. m.	10:55 a. m.	1.21	10:45 p. m.	11:19 p. m.	0.02	0.09	0.16	0.31	0.42	0.48	0.56	0.64							
	31	3:59 a. m.	5:55 a. m.	0.75	4:09 a. m.	4:22 a. m.	0.04	0.33	0.60	0.66											
Fort Wayne, Ind.	31			0.86														0.61			
Fort Worth, Tex.	5	4:21 a. m.	10:49 a. m.	1.38	8:17 a. m.	8:56 a. m.	0.19	0.10	0.16	0.36	0.49	0.51	0.60	0.71	0.79						
	10–11	2:48 p. m.	8:15 a. m.	1.62	3:42 p. m.	4:12 p. m.	0.30	0.05	0.15	0.29	0.44	0.61	0.70								
Fresno, Calif.	24–25			0.29														0.09			
Galveston, Tex.	4			1.86														0.59			
Grand Haven, Mich.	3	7:58 a. m.	8:48 a. m.	0.73	8:00 a. m.	8:09 a. m.	T.	0.42	0.68												
Grand Junction, Colo.	30–31			0.30														(*)			
Grand Rapids, Mich.	31			1.10														0.53			
Green Bay, Wis.	30			1.23														0.31			
Greenville, S. C.	22	5:30 p. m.	7:30 p. m.	2.26	5:50 p. m.	6:22 p. m.	0.04	0.09	0.27	0.58	0.88	1.14	1.43	1.56							
					7:07 p. m.	7:23 p. m.	1.72	0.08	0.23	0.51	0.54										
	22–23	8:00 p. m.	D. N. a. m.	1.38	12:36 a. m.	12:56 a. m.	0.74	0.07	0.17	0.41	0.58										
Hannibal, Mo.	4	1:55 p. m.	3:20 p. m.	0.65	2:40 p. m.	2:58 p. m.	0.07	0.05	0.22	0.47	0.53										
Harrisburg, Pa.	11–12			0.73														(*)			
Hartford, Conn.	16	7:10 p. m.	D. N. p. m.	0.73	7:47 p. m.	7:59 p. m.	0.05	0.27	0.50	0.57											
Hatteras, N. C.	23	7:15 a. m.	1:12 p. m.	1.29	7:39 a. m.	8:05 a. m.	0.09	0.13	0.23	0.35	0.55	0.66	0.67								
Havre, Mont.	21			0.25														0.25			
Helena, Mont.	22–23			0.43														(*)			
Houghton, Mich.	24			0.79														0.42			
Houston, Tex.	4	D. N. a. m.	5:56 a. m.	1.05	4:36 a. m.	5:05 a. m.	0.17	0.12	0.30	0.36	0.50	0.70	0.77								
		6:26 a. m.	10:14 a. m.	2.54	6:30 a. m.	7:30 a. m.	0.03	0.08	0.24	0.42	0.69	0.80	0.88	0.90	0.91	0.92	1.09	1.57			
	5	4:49 p. m.	6:05 p. m.	1.00	4:52 p. m.	5:23 p. m.	0.01	0.14	0.31	0.46	0.71	0.89	0.95	0.98							
	11	5:58 a. m.	12:13 p. m.	1.38	6:17 a. m.	6:45 a. m.	0.02	0.11	0.26	0.50	0.63	0.78	0.84								
	14	11:36 a. m.	2:20 p. m.	0.87	1:07 p. m.	1:21 p. m.	0.12	0.31	0.54	0.63											
Huron, S. Dak.	19			0.30														(*)			
Independence, Calif.	24			T.														T.			
Indianapolis, Ind.	9			1.24														0.74			
Iola, Kans.	25	8:00 p. m.	D. N. p. m.	1.22	9:27 p. m.	9:52 p. m.	0.41	0.09	0.20	0.30	0.41	0.61									
Jacksonville, Fla.	8			0.98														0.81			
Kansas City, Mo.	30			0.34														0.21			
Keokuk, Iowa	4			0.34														0.31			

* Self-register not in use.

[1] Estimated.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during October, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Key West, Fla.	16			0.73																	
Knoxville, Tenn.	13			1.25														0.37			
La Crosse, Wis.	30			1.81														0.55			
Lander, Wyo.	2-3			1.23														0.26			
Lansing, Mich.	31			0.81														(*)			
Lewiston, Idaho.	1			0.35														0.45			
Lexington, Ky.	9			0.63														0.27			
Lincoln, Nebr.	8			0.63														0.51			
Little Rock, Ark.	8–9	D. N. p. m.	D. N. a. m.	2.84	11:43 p. m.	11:59 p. m.	0.01	0.31	0.65	0.73	0.76							0.22			
	10–11	4:30 p. m.	8:35 a. m.	5.86	12:49 a. m.	2:01 p. m.	0.96	0.09	0.23	0.48	0.62	0.68	0.74	0.84	0.93	0.99	1.04	1.07	1.71		
					7:25 p. m.	8:09 p. m.	0.65	0.09	0.20	0.21	0.22	0.22	0.57	0.85	1.11	1.22					
	21	D. N. a. m.	1:50 p. m.	2.17	1:08 a. m.	1:53 a. m.	3.56	0.13	0.25	0.29	0.40	0.62	0.77	0.87	0.95	1.06					
					3:03 a. m.	3:27 a. m.	0.04	0.14	0.35	0.42	0.50	0.54									
Los Angeles, Calif.	24			0.55																	
Louisville, Ky.	26	7:30 a. m.	8:15 a. m.	0.54	7:42 a. m.	8:00 a. m.	0.01	0.17	0.30	0.46	0.52							0.12			
Ludington, Mich.	30			1.11																	
Lynchburg, Va.	12			0.61														0.32			
Macon, Ga.	22	7:52 p. m.	8:35 p. m.	0.58	7:55 p. m.	8:15 p. m.	0.02	0.17	0.39	0.44	0.53							0.35			
	23	11:31 a. m.	7:35 p. m.	1.48	6:29 p. m.	6:52 p. m.	0.83	0.21	0.41	0.48	0.59	0.64									
Madison, Wis.	3–4	D. N. p. m.	D. N. a. m.	1.33	12: mdt.	12:35 a. m.	0.01	0.22	0.43	0.49	0.60	0.65	0.69	0.78							
Marquette, Mich.	1			0.75																	
Memphis, Tenn.	5	6:07 p. m.	D. N. p. m.	0.88	7:09 p. m.	7:49 p. m.	0.16	0.09	0.23	0.30	0.41	0.46	0.52	0.55	0.65			0.40			
	31	5:40 p. m.	D. N. p. m.	1.37	5:06 p. m.	5:55 p. m.	0.01	0.08	0.10	0.15	0.20	0.29	0.45	0.66	1.02	1.15	1.22				
Meridian, Miss.	4	6:30 a. m.	9:00 a. m.	0.89	6:37 a. m.	6:56 a. m.	0.01	0.10	0.25	0.45	0.54										
Miami, Fla.	17	6:20 a. m.	9:10 a. m.	1.15	7:12 a. m.	7:22 a. m.	0.47	0.29	0.59												
Milwaukee, Wis.	30–31	7:05 p. m.	D. N. a. m.	1.49	8:48 p. m.	9:15 p. m.	0.07	0.14	0.31	0.39	0.55	0.63	0.68								
Minneapolis, Minn.	24			0.34																	
Mobile, Ala.	11	6:10 a. m.	1:40 p. m.	2.09	8:52 a. m.	9:08 a. m.	0.53	0.10	0.35	0.54	0.60							0.24			
	22	3:55 p. m.	8:45 p. m.	0.92	10:51 a. m.	11:14 a. m.	1.19	0.06	0.23	0.38	0.50	0.65									
Modena, Utah.	6			0.35	4:33 p. m.	4:46 p. m.	0.02	0.29	0.50												
Montgomery, Ala.	4	3:05 p. m.	3:45 p. m.	0.55	3:05 p. m.	3:16 p. m.	0.00	0.28	0.45	0.51								0.16			
	16	6:50 p. m.	D. N. p. m.	1.21	7:08 p. m.	7:31 p. m.	0.03	0.28	0.62	0.77	0.87	0.93									
	30	D. N. a. m.	D. N. a. m.	0.94	12:26 a. m.	12:44 a. m.	0.06	0.19	0.36	0.49	0.55										
Moorhead, Minn.	20			0.34																	
Mount Tamalpais, Calif.	1			0.74														(*)			
Nantucket, Mass.	21			1.07														0.43			
Nashville, Tenn.	31–1	6:45 p. m.	9:00 a. m.	2.60	8:41 p. m.	9:08 p. m.	0.08	0.16	0.30	0.34	0.40	0.51	0.55					0.46			
New Haven, Conn.	11			0.51																	
New Orleans, La.	4	11:46 a. m.	12:30 p. m.	0.57	11:53 a. m.	12:12 p. m.	0.03	0.18	0.35	0.45	0.53							0.43			
	22	4:02 p. m.	6:58 p. m.	0.67	4:04 p. m.	4:25 p. m.	0.01	0.15	0.24	0.35	0.47	0.50									
New York, N. Y.	11			0.36																	
Norfolk, Va.	24			0.91														0.36			
North Head, Wash.	26			0.14														0.58			
North Platte, Nebr.	15			0.41														0.13			
Oklahoma, Okla.	4	12:50 p. m.	4:55 p. m.	1.35	1:32 p. m.	2:36 p. m.	0.18	0.06	0.22	0.39	0.49	0.54	0.65	0.70	0.72	0.76	0.78	0.95	1.05		
Omaha, Nebr.	4			0.50														0.58			
Oswego, N. Y.	5–6			1.13																	
Palestine, Tex.	3	10:11 a. m.	11:27 a. m.	0.66	10:46 a. m.	11:00 a. m.	0.12	0.12	0.34	0.52								(*)			
	22	D. N. a. m.	11:25 a. m.	1.72	12:35 a. m.	1:02 a. m.	0.01	0.34	0.63	0.80	0.89	0.96	0.99								
		2:45 p. m.	6:10 p. m.	0.78	3:59 p. m.	4:17 p. m.	0.04	0.05	0.45	0.60	0.64										
Parkersburg, W. Va.	31			1.07																	
Pensacola, Fla.	21	5:15 a. m.	6:20 a. m.	0.68	5:58 a. m.	6:09 a. m.	0.16	0.20	0.49	0.51								0.35			
	22	4:30 a. m.	6:02 a. m.	0.74	5:18 a. m.	5:52 a. m.	0.17	0.06	0.14	0.23	0.23	0.41	0.51	0.57							
	29	3:10 a. m.	6:20 a. m.	1.02	3:15 a. m.	3:38 a. m.	0.02	0.15	0.27	0.34	0.57	0.65									
Peoria, Ill.	16			0.25																	
Philadelphia, Pa.	16			0.44														0.21			
Phoenix, Ariz.	24			0.22														0.43			
Pierre, S. Dak.	19			0.96														0.04			
Pittsburgh, Pa.	16			1.15														(*)			
Pocatello, Idaho.	1			0.54														0.60			
Point Reyes Light, Calif.	24			0.20														0.15			
Port Angeles, Wash.	1			0.74														0.13			
Port Huron, Mich.	30			0.88														0.16			
Portland, Me.	3			0.50														0.23			
Portland, Oreg.	1			0.46														0.22			
Providence, R. I.	6			0.23														0.15			
Pueblo, Colo.	7			0.16														0.16			
Raleigh, N. C.	12			0.46														0.16			
Rapid City, S. Dak.	18–19			1.20														0.35			
Reading, Pa.	16			0.40														(*)			
Red Bluff, Calif.	1			0.24														0.34			
Reno, Nev.	24			0.16														0.22			
Richmond, Va.	12			0.50														(*)			
Rochester, N. Y.	6			1.12														0.18			
Roseburg, Oreg.	1			1.00														0.57			
Roswell, N. Mex.	6			0.41														0.27			
Sacramento, Calif.	1			0.01														0.26			
Saginaw, Mich.	10	11:38 a. m.	12:40 p. m.	0.61	11:54 a. m.	12:11 p. m.	0.06	0.22	0.38	0.51	0.54							T.			
St. Joseph, Mo.	8			0.72																	
St. Louis, Mo.	31			1.04														0.84			
St. Paul, Minn.	24			0.35														0.61			
Salt Lake City, Utah.	14			0.49														(*)			
San Antonio, Tex.	10–11	9:55 p. m.	7:16 a. m.	1.61	9:55 p. m.	11:05 p. m.	0.00	0.13	0.27	0.29	0.32	0.35	0.36	0.40	0.47	0.64	0.76	0.43			
	20	4:07 p. m.	6:39 p. m.	0.81	4:24 p. m.	4:42 p. m.	0.10	0.24	0.51	0.61	0.67							1.04	1.28		
San Diego, Calif.	24			1.00																	
Sandusky, Ohio.	31			0.62														0.32			
Sandy Hook, N. J.	16			0.37														0.43			
San Francisco, Calif.	1			0.17														0.36			
San Jose, Calif.	24			0.28														0.07			
San Luis Obispo, Calif.	24			0.12														0.20			
Santa Fe, N. Mex.	7			0.55														0.04			
Sault Ste. Marie, Mich.	30–31			1.22														0.20			
Savannah, Ga.	22			0.49														(*)			
Scranton, Pa.	16			0.36														0.41			
Seattle, Wash.	22			0.23														0.28			
Sheridan, Wyo.	18–19			0.77														0.22			
																		(*)			

*Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during October, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Shreveport, La.	7	D. N. a. m.	11:45 a. m.	2.20	6:43 a. m.	7:45 a. m.	0.57	0.12	0.22	0.26	0.29	0.36	0.43	0.46	0.58	0.70	0.74	0.86	0.97	.....	.....
	22	3:50 p. m.	8:25 p. m.	2.28	5:34 p. m.	6:20 p. m.	0.23	0.24	0.63	0.87	0.99	1.05	1.14	1.28	1.38	1.50	1.52	.....	.....	.....	.....
Sioux City, Iowa	8	.....	.....	0.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....
Spokane, Wash.	28	.....	.....	0.17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....
Springfield, Ill.	31	.....	.....	0.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.46	.....	.....	.....
Springfield, Mo.	25–26	7:33 p. m.	6:02 a. m.	1.69	1:46 a. m.	2:14 a. m.	0.39	0.17	0.34	0.54	0.63	0.69	0.74	.....	.....	.....	.....	.....	.....	.....	.....
Syracuse, N. Y.	26	.....	.....	0.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.54	.....	.....	.....
Tacoma, Wash.	31	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.16	.....	.....	.....
Tampa, Fla.	29	D. N. a. m.	8:20 a. m.	0.68	6:33 a. m.	6:59 a. m.	0.06	0.11	0.15	0.27	0.39	0.48	0.50	.....	.....	.....	.....	.....	.....	.....	.....
Tatoosh Island, Wash.	27	.....	.....	1.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....
Taylor, Tex.	10–11	6:05 p. m.	8:30 a. m.	2.36	10:09 p. m.	11:47 p. m.	0.32	0.11	0.23	0.33	0.35	0.39	0.50	0.58	0.62	0.71	0.75	0.82	1.04	1.37	.....
	15	6:50 a. m.	1:54 p. m.	1.65	8:40 a. m.	9:10 a. m.	0.36	0.14	0.22	0.42	0.61	0.71	0.78	.....	.....	.....	.....	.....	.....	.....	.....
Terre Haute, Ind.	31	7:10 a. m.	1:25 p. m.	1.33	8:28 a. m.	8:57 a. m.	0.14	0.09	0.12	0.18	0.29	0.44	0.55	.....	.....	.....	.....	.....	.....	.....	.....
Thomasville, Ga.	8	.....	.....	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.15	.....	.....	.....
Toledo, Ohio	30	.....	.....	0.51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.39	.....	.....	.....
Tonopah, Nev.	24	.....	.....	0.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....
Topeka, Kans.	8	.....	.....	0.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.18	.....	.....	.....
Trenton, N. J.	12	.....	.....	1.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.17	.....	.....	.....
Valentine, Nebr.	19	.....	.....	0.37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.12	.....	.....	.....
Vicksburg, Miss.	7–8	D. N. p. m.	D. N. a. m.	1.64	12:17 a. m.	12:51 a. m.	0.14	0.06	0.15	0.35	0.72	1.02	1.24	1.42	.....	.....	.....	.....	.....	.....	.....
Walla Walla, Wash.	1–2	.....	.....	0.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....
Washington, D. C.	1	.....	.....	1.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.70	.....	.....	.....
Wausau, Wis.	24	.....	.....	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Wichita, Kans.	8	.....	.....	0.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....
Williston, N. Dak.	29–30	.....	.....	1.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....
Wilmington, N. C.	23	.....	.....	0.37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.37	.....	.....	.....
Winnemucca, Nev.	1	.....	.....	0.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....
Wytheville, Va.	3	.....	.....	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.48	.....	.....	.....
Yankton, S. Dak.	19	.....	.....	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.17	.....	.....	.....
Yellowstone Park, Wyo.	22–23	.....	.....	1.19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....

*Self-register not in use. ‡No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, October, 1919.*

Stations.	Altitude above M. S. L. Jan. 1, 1919.	Pressure.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.83	29.97	+0.06	42.0	− 3.4	48.0	36.0	60	25	3.33	−2.00	T.
Sydney, C. B. I.	48	30.04	30.09	+0.13	45.1	− 1.4	54.1	37.0	66	28	3.10	−1.59	T.
Halifax, N. S.	88	30.00	30.11	+0.11	46.3	− 0.9	54.8	37.9	68	25	4.38	−1.17	T.
Yarmouth, N. S.	65	30.03	30.10	+0.08	46.2	− 1.4	53.6	38.8	61	25	5.20	+0.50	.....
Charlottetown, P. E. I.	38	30.03	30.07	+0.11	44.5	− 1.9	51.1	38.0	62	26	4.22	−0.68	.....
Chatham, N. B.	28	30.08	30.11	+0.15	42.4	− 0.6	51.2	33.7	63	20	2.34	−1.52	1.5
Father Point, Que.	20	30.04	30.06	+0.11	38.0	− 1.8	44.6	31.4	59	22	1.36	−1.54	1.6
Quebec, Que.	296	29.76	30.09	+0.09	42.3	− 0.1	49.4	35.2	61	23	3.37	+0.22	.....
Montreal, Que.	187	29.88	30.09	+0.08	45.8	+ 1.0	52.6	38.9	72	27	5.23	+2.10	T.
Stonecliffe, Ont.	489	29.42	30.04	+0.03	37.9	− 4.9	52.9	23.0	72	10	5.40	+2.97	.....
Ottawa, Ont.	236	29.82	30.09	+0.08	46.8	+ 3.0	55.5	38.1	78	27	5.11	+2.56	T.
Kingston, Ont.	285	29.76	30.07	+0.04	52.5	+ 5.5	60.6	44.4	72	30	3.56	+0.83	.....
Toronto, Ont.	379	29.66	30.07	+0.03	53.0	+ 6.4	61.5	44.6	80	32	2.97	+0.61	.....
Cochrane, Ont.	930	.....	.....	.....	53.6	.....	42.6	28.6	64	12	2.71	.....	6.0
White River, Ont.	1,244	28.64	29.98	.....	35.1	− 2.0	44.5	25.8	68	13	3.39	+0.36	5.2
Port Stanley, Ont.	592	29.43	30.07	+0.02	52.8	+ 5.0	60.5	45.0	72	30	3.99	+1.01	.....
Southampton, Ont.	656	29.32	.....	.....	51.5	+ 5.4	58.8	44.2	75	30	3.87	+0.70	.....
Parry Sound, Ont.	688	29.36	30.06	+0.05	47.8	+ 3.9	56.4	39.3	71	23	7.10	+3.18	.....
Port Arthur, Ont.	644	29.29	30.00	+0.02	38.7	− 3.9	46.9	30.4	70	16	1.53	−1.03	0.6
Winnipeg, Man.	760	29.17	30.03	+0.05	33.3	− 5.8	42.4	24.3	75	3	0.12	+0.58	15.2
Minnedosa, Man.	1,690	28.17	29.94	−0.03	29.8	− 8.0	39.9	19.7	67	−11	0.61	+0.49	8.3
Le Pas, Man.	860	.....	.....	.....	.....	.....	34.2	20.0	56	2	1.78	.....	3.5
Qu'Appelle, Sask.	2,115	27.71	30.02	+0.05	28.0	−11.4	39.0	17.1	72	−14	0.71	+0.39	12.4
Medicine Hat, Alb.	2,144	27.66	29.96	−0.01	35.3	− 9.5	48.0	22.7	78	− 6	0.01	+0.57	3.1
Moose Jaw, Sask.	1,759	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Swift Current, Sask.	2,392	27.37	30.05	+0.08	30.4	−11.7	42.6	18.2	75	−10	0.02	+0.86	5.1
Calgary, Alb.	3,428	26.41	30.06	+0.11	32.8	− 7.3	46.5	19.2	74	− 7	0.30	−0.18	3.2
Banff, Alb.	4,521	25.35	30.02	+0.07	31.5	− 7.7	42.5	20.5	65	− 5	0.22	−0.80	4.0
Edmonton, Alb.	2,150	27.67	30.01	+0.08	29.1	− 2.0	40.2	18.0	67	−15	0.47	−0.23	18.1
Prince Albert, Sask.	1,450	28.44	30.05	+0.08	28.0	− 9.1	37.5	18.6	64	− 4	0.45	−0.28	2.8
Battleford, Sask.	1,592	28.23	30.01	+0.04	28.7	−10.9	39.9	17.5	69	−15	0.06	−0.39	7.2
Kamloops, B. C.	1,262	28.85	30.17	+0.21	42.1	− 4.9	50.4	33.7	74	21	1.05	+0.44	1.8
Victoria, B. C.	230	29.87	30.13	+0.12	48.2	− 1.0	53.9	42.4	67	32	2.76	+0.39	3.7
Barkerville, B. C.	4,180	25.67	30.04	+0.10	30.2	− 9.5	37.3	23.1	67	− 4	3.53	+0.53	25.7
Triangle Island, B. C.	680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prince Rupert, B. C.	170	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hamilton, Ber.	151	29.99	30.15	+0.13	76.0	+ 3.0	81.9	70.1	85	65	2.57	−4.14	.....

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Dec. 3, 1919.]

TABLE I.—*Noninstrumental earthquake reports, October, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1919.	*H. m.*		° ′	° ′			*Sec.*			
Oct. 1	18 42	Calexico	32 41	115 30	4	1	5	None	Felt by many	H. M. Rouse.
	21 46	do	32 41	115 30	3	1	2	Faint rumbling	Rapid vertical motion. Felt by many.	Do.
	23 50	do	32 41	115 30	5	1	1	do	Felt by many	Do.
2	7 31	do	32 41	115 30	5	1	70	do	do	Do.
4	6 15	do	32 41	115 30	3	1	8	Loud rumbling	do	Do.
	15 57	do	32 41	115 30	3	1	4	Faint rumbling	Felt by several	Do.
5	2 36	Eureka	40 45	124 15	3	1	2	None	do	L. B. Cooper.
13	20 35	Salinas	36 36	121 40	3	1		do	do	E. D. Eddy.
25	22 40	do	36 36	121 40	3	1		do	do	Do.
31	0 36	Lucerne Valley	34 27	116 57	3	1		do		J. M. Henry.

TABLE 2.—*Instrumental seismological reports, October, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(No earthquake recorded during October, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 03″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		*V*	T_0
	E	10	17
	N	10	15

(No earthquake recorded during October, 1919.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		*V*	T_0
	E	10	15
	N	10	18

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Oct. 1	.....	P_E	18 43 15	.....	.....	.....	.....	N not in operation during October.
		M_E	18 44 13	2	[illegible]	.....	.....	
		F_E	18 45 ..	.....	.....	.....	.....	
1	.....	iP_E	19 32 16	2	.....	.....	.....	
		L_E	19 33 12	.....	.....	.....	.....	
		M_E	19 33 55	.....	230	.....	.....	
		C_E	19 35 ..	.....	.....	.....	.....	
		F_E	19 45 ..	5	.....	.....	.....	
1	.....	ePg_E	21 48 40	.....	.....	.....	.....	
		M_E	21 49 07	3	10	.....	.....	
		F_E	21 53 ..	.....	.....	.....	.....	
10	.....	eP_E	2 11 09	.....	.....	.....	.....	P indefinite.
		L_E	2 17 30	.....	.....	.....	.....	
		M_E	2 17 38	.....	20	.....	.....	
		F_E	2 27 ..	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Oct. 5	.....	.....	.....	.....	100	200	.....	Tremors during 24 hours preceding 15 h.
7	.....	.....	.....	.....	200	200	.....	Tremors during 24 hours preceding 15 h.
8	.....	.....	.....	.....	100	200	.....	Tremors during 24 hours preceding 15 h.

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Oct. 1	Ii.....	L_E	19 36 30	.....	.....	.....	.....	P. not discernible. Distinct wavelets at intervals during day.
		L_N	19 36 30	.....	.....	.....	.....	
		M_E	19 37 ..	6	*2,000	.....	.....	
		M_N	19 37 ..	6	.....	*2,800	.....	
		F_E	19 38 ..	.....	.....	.....	.....	
		F_N	19 38 ..	.....	.....	.....	.....	
10	Ie.....	L_E	1 15 ..	12	.....	.....	.....	Regular sinusoidal. P. and M. not discernible. Wavelets very clear at intervals during day.
		L_N	1 15 ..	?	.....	.....	.....	
		F_E	1 35 ..	.....	.....	.....	.....	
		F_N	1 35 ..	.....	.....	.....	.....	
12–13	.....	.....	.....	.....	.....	.....	.....	Distinct activity at intervals during day.
15–16	.....	.....	.....	.....	.....	.....	.....	Wavelets visible at intervals during day.
20–21	.....	.....	.....	.....	.....	.....	.....	Thickening of penmarks at intervals during day. Doubtful as to being seismic.

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, October, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. U. S. Weather Bureau.*								
Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.								
Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.								
Instrumental constants.. V 110 T_0 6.4								
1919.			*H. m. s.*	*Sec.*	*μ.*	*μ.*	*Km.*	
Oct. 1	.....	e.....	19 48 12	.....	.....	.....	.....	Heavy micros.
		L.....	19 49 12	.....	.....	.....	.....	
		F.....	20 *ca*	.....	.....	.....	.....	Lost in micros.
3	.....	e.....	10 30 00	.....	.....	.....	.....	
		L.....	10 32 30	20	.....	.....	.....	
		F.....	10 50 *ca*	.....	.....	.....	.....	Heavy micros.
10	.....	.....	.....	.....	.....	.....	.....	Earthquake between 1 h. and 2 h. *ca.*; small disturbances lasting nearly an hour. Clock not working.
12	.....	iP.....	.....	.....	.....	.....	.....	Earthquake shortly after 22 h. L waves about one hour later. Whole disturbance lasting about 1 h. 20 m. Clock not working.
14	.....	.....	.....	.....	.....	.....	.....	Earthquake between 17 h. and 18 h., lasting a half hour *ca.* Clock not working.
27	.....	P.....	3 52 30?	.....	.....	.....	.....	Time uncertain.
		S.....	4 00 00?	.....	.....	.....	.....	
		eL.....	4 10 *ca*	.....	.....	.....	.....	
		F.....	4 20 *ca*	.....	.....	.....	.....	
28	.....	P.....	7 29 15?	.....	.....	.....	.....	Time uncertain.
		S.....	7 33 45?	.....	.....	.....	.....	
		F.....	7 50 *ca*	.....	.....	.....	.....	
District of Columbia. *Washington. Georgetown University.*								
F. A. Tondorf, S. J.								
Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.								
Instruments: Wiechert 200 kg. astatic horizontal pendulum, 80 kg. vertical.								
Instrumental constants..			V	T_0	ϵ			
		E	165	5.4	0			
		N	143	5.2	0			
		Z	*80*	*5.0*	*0*			
1919.			*H. m. s.*	*Sec.*	*μ.*	*μ.*	*Km.*	
Oct 1[1]	.....	e_E.....	19 48 23	.....	.....	.....	.....	Very heavy micros.
		e_N.....	19 48 00	.....	.....	.....	.....	
		F.....	20 10 ..	.....	.....	.....	.....	
3	.....	e_E.....	10 07 33	.....	.....	.....	.....	Heavy micros.
		eL_N.....	10 30 24	11	.....	.....	.....	
		L_E.....	10 34 16	21	.....	.....	.....	
		F.....	11 *ca*	.....	.....	.....	.....	
10	.....	eP_E.....	1 14 18	.....	.....	.....	.....	Heavy micros
		eP_N.....	1 14 18	.....	.....	.....	.....	
		L_E.....	1 28 28	14	.....	.....	.....	
		L_N.....	1 28 28	14	.....	.....	.....	
		F.....	2 15 ..	.....	.....	.....	.....	
		VERTICAL.						
10	.....	eP_Z.....	*1 14 23*	.....	.....	.....	.....	
		L_Z.....	*1 30 32*	*14*	.....	.....	.....	
		F_Z.....	*2 10* ..	.....	.....	.....	.....	
12	.....	eP_E.....	22 08 14	.....	.....	.....	.....	Very heavy micros.
		iP_N.....	22 08 14	.....	.....	.....	.....	
		S_N?.....	22 11 34	.....	.....	.....	.....	F impossible.

[1] Because of repairs going on in cave, seismograms for the month are difficult to evaluate.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.								
Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.								
Instrument: Mine seismograph of the Seismological Committee of the British Association.								
T_0								
Instrumental constant 18.4. Sensitivity, 0.49″.								
(Report for October, 1919, not received.)								
Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.								
Lat., 41° 47′ N.; long., 87° 37′ W. Elevation 189.1 meters.								
Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.								
Instrumental constants..			V	T_0	ϵ	Sensitivity.		
		E.	150	12	20:1	1″ arc tilt=26.6 mm.		
		N.	150	8	20:1	1″ arc tilt=13.2 mm.		
1919.			*H. m. s.*	*Sec.*	*μ.*	*μ.*	*Km.*	
Oct. 1	.....	e.....	19 44 7	.....	.....	.....	.....	Heavy micros.
		M.....	19 45 00	.....	.....	11	.....	
		F.....	19 55 *ca*	.....	.....	.....	.....	Lost in micros.
3	.....	P.....	10 02 8	.....	.....	.....	.....	
		PR_1.....	10 04 38	.....	.....	.....	.....	
		S.....	10 10 6	.....	.....	.....	.....	
		L.....	10 25 00	.....	.....	.....	.....	
		L.....	10 30 00	15	.....	.....	.....	
		F.....	12 20 *ca*	.....	.....	.....	.....	Heavy micros.
5	.....	e.....	2 54 00	.....	.....	.....	.....	
		L.....	2 55 30	15	.....	.....	.....	
		F.....	3 07 *ca*	.....	.....	.....	.....	Micros.
8	.....	P?.....	5 09 48	.....	.....	.....	.....	
		L.....	5 37 00	30	.....	.....	.....	
		L.....	5 42 00	22	.....	.....	.....	
		L.....	5 53 00	18	.....	.....	.....	
		F.....	7 10 *ca*	.....	.....	.....	.....	Micros.
8	.....	P?.....	22 49 55	.....	.....	.....	.....	
		S?.....	22 53 25	.....	.....	.....	.....	
		L.....	22 56 10	22	.....	.....	.....	
		F.....	23 15 *ca*	.....	.....	.....	.....	Heavy micros.
10	.....	P.....	1 12 40	.....	.....	.....	3,070	
		S.....	1 17 38	.....	.....	.....	.....	
		L.....	1 23 45	15	.....	.....	.....	
		F.....	3 30 *ca*	.....	.....	.....	.....	Heavy micros.
12	.....	iP.....	22 11 5	.....	.....	.....	.....	
		S?.....	22 20 25	.....	.....	.....	.....	
		L.....	22 54 00	40	.....	.....	.....	
		L.....	23 00 00	25	.....	.....	.....	
		L.....	23 15 00	22	.....	.....	.....	
		L.....	23 36 00	18	.....	.....	.....	
		L.....	23 52 00	15	.....	.....	.....	
13	.....	F.....	0 30 *ca*	.....	.....	.....	.....	
14	.....	P.....	12 03 23	.....	.....	.....	.....	
		L.....	12 10 00	18	.....	.....	.....	
		L.....	12 20 00	15	.....	.....	.....	
		F.....	12 50 *ca*	.....	.....	.....	.....	
14	.....	P.....	17 02 8	.....	.....	.....	.....	
		S?.....	17 05 12	.....	.....	.....	.....	
		L.....	17 07 00	.....	.....	.....	.....	
		F.....	18 *ca*	.....	.....	.....	.....	
21	.....	eL.....	22 21 00	.....	.....	.....	.....	
		L.....	22 27 00	18	.....	.....	.....	
		F.....	23 *ca*	.....	.....	.....	.....	
27	.....	P.....	3 50 37	.....	.....	.....	6,200	
		S.....	3 58 22	.....	.....	.....	.....	
		L.....	4 07 00	.....	.....	.....	.....	
		F.....	5 *ca*	.....	.....	.....	.....	
28	.....	.....	7 35 to 8 10 ..	.....	.....	.....	.....	Disturbances mixed with extremely heavy micros.

TABLE 2.—*Instrumental seismological reports, October, 1919.*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Weichert.

Instrumental constants..		V	T_0	ε
	E	177	3.4	4:1
	N	205	3.4	4:1

(Report for October, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	14
	N	10	14

1919.			H. M. S.	Sec.	μ	μ	Km.	
Oct. 10	.....	eP_E	1 16 00	.....	.....	.....	.....	Phases indefinite. P very faint.
		eP_N	1 19 45	.....	.....	.....	.....	
		L_E	1 28 50	.....	.....	.....	.....	
		L_N	1 28 10	.....	.....	.....	.....	
		M_E	1 33 50	8	20	.....	.....	
		M_N	1 29 10	14	.....	20	.....	
		C_E	1 35 ..	8	.....	.....	.....	
		C_N	1 32 ..	10	.....	.....	.....	
		F_E	2 04 ..	8	.....	.....	.....	
		F_N	2 13 ..	9	.....	.....	.....	
			..					
14	.....	P_E	17 01 58	.....	.....	.....	.....	
		P_N	17 02 01	.....	.....	.....	.....	
		L_E	17 07 00	.....	.....	.....	.....	
		L_N	17 07 10	.....	.....	.....	.....	
		M_E	17 17 25	8	10	.....	.....	
		M_N	17 09 10	12	.....	10	.....	
		F	17 22 ..	8	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacia sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants..		V	T_0	ε
	E	80	23	0
	N	50	25	4:1

(Report for October, 1919, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	ε
	80	7	5:1

Report for October, 1919, not received.)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

New York *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori 25 kg. horizontal pendulums (mechanical registration.)

Instrumental constants..		V	T_0	ε
	E	13	22	4:1
	N	14	25	4:1

(Report for October, 1919, not received.)

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..		V	T_0	ε
	E	72	5.0	0
	N	72	5.0	0

(Report for October, 1919, not received.)

Panama, Canal Zone. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants..	V	T_0
	35	20

1919.			H. M. S.	Sec.	μ.	μ.		
Oct. 9	.....	P_E	9 00 34	.....	.....	.....	183	Probably S. W.
		P_N	9 00 28	.....	.....	.....	.....	
		L_E	9 00 54	.....	.....	.....	.....	
		L_N	9 00 48	.....	.....	.....	.....	
		M_E	9 00 59	.....	*3,500	.....	.....	
		M_N	9 00 54	.....	.....	*3,000	.....	
		F_E	9 03 44	.....	.....	.....	.....	
		F_N	9 03 32	.....	.....	.....	.....	
27	.....	P_N	3 45 48	.....	.....	.....	2,776 ca	Record not clearly defined on the E. W. component.
		S_N	3 50 25	.....	.....	.....	.....	
		L_N	3 54 48	.....	.....	.....	.....	
		M_N	3 50 40	.....	.....	600	.....	
		F_N	4 17 00	.....	.....	.....	.....	

*Trace amplitude.

Porto Rico. *Viegues. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long. 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	17
	N	10	19

(Report for October, 1919, not received.)

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omri, mechanical registration.

Instrumental constants..		V	T_0
	E	10	15
	N	10	16

(No earthquake recorded during October, 1919.)

TABLE 2.—*Instrumental seismological reports, October, 1919*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoye 80 kg. vertical seismograph.

Instrumental constants. $\frac{V}{120}$ $\frac{T_0}{26}$

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1919. Oct. 1	.....	i_N	19 49 11	.....	.....	.....	.....	Irregular waves mixed with heavy micros.
		F	19 54 ..	.....	.....	.....	.....	
3	.....	e_E	10 06 30	.....	.....	.....	.....	Heavy micros.
		i_E	10 12 40	.....	.....	.....	.....	
		iL_N	10 30 23	11	.....	.....	.....	
		eL_E	10 31 ..	24	.....	.....	.....	
		L_E	10 35 ..	21	.....	.....	.....	
		L	10 40 ..	15	.....	.....	.....	
		L_E	10 49 ..	13	.....	.....	.....	
		L_E	11 00 ..	13	.....	.....	.....	
		L_E	11 11 ..	12	.....	.....	.....	
		F	11 15 ..	.....	.....	.....	.....	
8	.....	eL_E	5 40 ..	.....	.....	.....	.....	Very faint traces of sinusoidal L waves. Heavy micros.
		F	5 55 ..	.....	.....	.....	.....	
10	.....	0	1 10 07	.....	.....	.....	2,560	
		P_E	1 15 20	.....	.....	.....	.....	Heavy micros.
		S_E	1 19 30	.....	.....	.....	.....	
		eL	1 24 48	.....	.....	.....	.....	
		L	1 29 ..	12	.....	.....	.....	
		L_E	1 30 ..	.....	.....	.....	.....	Very irregular and small L waves after 1 h. 30 m.
		L_E	2 15 ..	.....	.....	.....	.....	
		F	2 20 ..	.....	.....	.....	.....	
12	.....	i_N	22 10 55	.....	.....	.....	.....	Heavy micros obscure all earlier phases.
		i_E	22 11 46	.....	.....	.....	.....	
		eL_E	22 55 ..	35	.....	.....	.....	
		L_E	23 05 ..	20	.....	.....	.....	
		F	23 40 ..	.....	.....	.....	.....	
14	.....	e	17 13 ..	.....	.....	.....	.....	Irregular small waves.
		F	17 25 ..	.....	.....	.....	.....	
21	.....	eL	22 25 ..	.....	.....	.....	.....	Very faint sinusoidal L waves. Barely discernible.
		F	22 50 ..	.....	.....	.....	.....	
27	.....	O	3 40 47	.....	.....	.....	6,560	
		P_N	3 50 50	.....	.....	.....	.....	Heavy micros prevent very accurate readings of initial impulses.
		S	3 58 56	.....	.....	.....	.....	
		eL_E	4 08 ..	.....	.....	.....	.....	
		L_E	4 10 ..	.....	.....	.....	.....	
		F	4 25 ..	.....	.....	.....	.....	
28	.....	$e?_E$	7 36 24	.....	.....	.....	.....	Very faint record. Barely discernible.
		$eL?_E$	7 40 17	.....	.....	.....	.....	
		F	7 50 ..	.....	.....	.....	.....	

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant $\frac{T_0}{18}$. Pillar deviation, 1 mm. swing of boom=0.45″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1919. Oct. 1	.....	.....	.....	.....	.....	.....	.....	Micros on sheet when other station records quake.
3	.....	E	10?02 00	.....	.....	.....	.....	Times doubtful, watch under repairs.
		E	10 06 24	.....	.....	.....	.....	
		S?	10 12 36	.....	.....	.....	.....	
		L	10 19 36	.....	.....	.....	.....	
		L	10 23 06	.....	.....	.....	.....	
		L	10 32 12	.....	.....	.....	.....	
		eL	10 33 36	.....	.....	.....	.....	
		M	10 39 42	.....	*1,300	.....	.....	
		F	.....	.....	.....	.....	.....	

Canada. *Toronto. Dominion Meteorological Service*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1919. Oct. 3	.....	L	11 51 48	.....	.....	.....	.....	
		eL	11 59 18	.....	.....	.....	.....	
		M	12?05 54	.....	*300	.....	.....	Marked thickening.
8	.....	i	5 30 42	.....	.....	.....	.....	Times very doubtful, no cut-off.
		eL	5 43 48	.....	.....	.....	.....	
		eL	5 52 00	.....	.....	.....	.....	
		M	5 58 36	.....	*300	.....	.....	
		L	6?27 36	.....	.....	.....	.....	
		L	6?55 06	.....	.....	.....	.....	
		F	6?58 00	.....	.....	.....	.....	
10	.....	eL	1 25 54	.....	.....	.....	.....	Times very doubtful.
		iL	1 27 54	.....	.....	.....	.....	
		M	1 28 00	.....	*1,300	.....	.....	
		F	2 12 00	.....	.....	.....	.....	
12	.....	L	23 10 18	.....	.....	.....	.....	Times doubtful.
		M	23 14 36	.....	*200?	.....	.....	
21	.....	E	22 25 48	.....	.....	.....	.....	
		eL	22 32 54	.....	.....	.....	.....	
		M	22 35 30	.....	*100	.....	.....	
		F	.....	.....	.....	.....	.....	
27	.....	i?	3?47 30	.....	.....	.....	.....	Isolated micros, render initial phases doubtful.
		P	3?51 06	.....	.....	.....	.....	
		S	3 59 18	.....	.....	.....	.....	
		eL	4 10 30	.....	.....	.....	.....	
		M	4 12 30	.....	*300	.....	6?680	
		F	4 36 30	.....	.....	.....	.....	
28	.....	L	7 41 42	.....	.....	.....	.....	
		L	7 48 18	.....	.....	.....	.....	
		M	7 49 12	.....	*200	.....	.....	
		F	7 54 42	.....	.....	.....	.....	

* Trace amplitude.

Canada. *Victoria B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

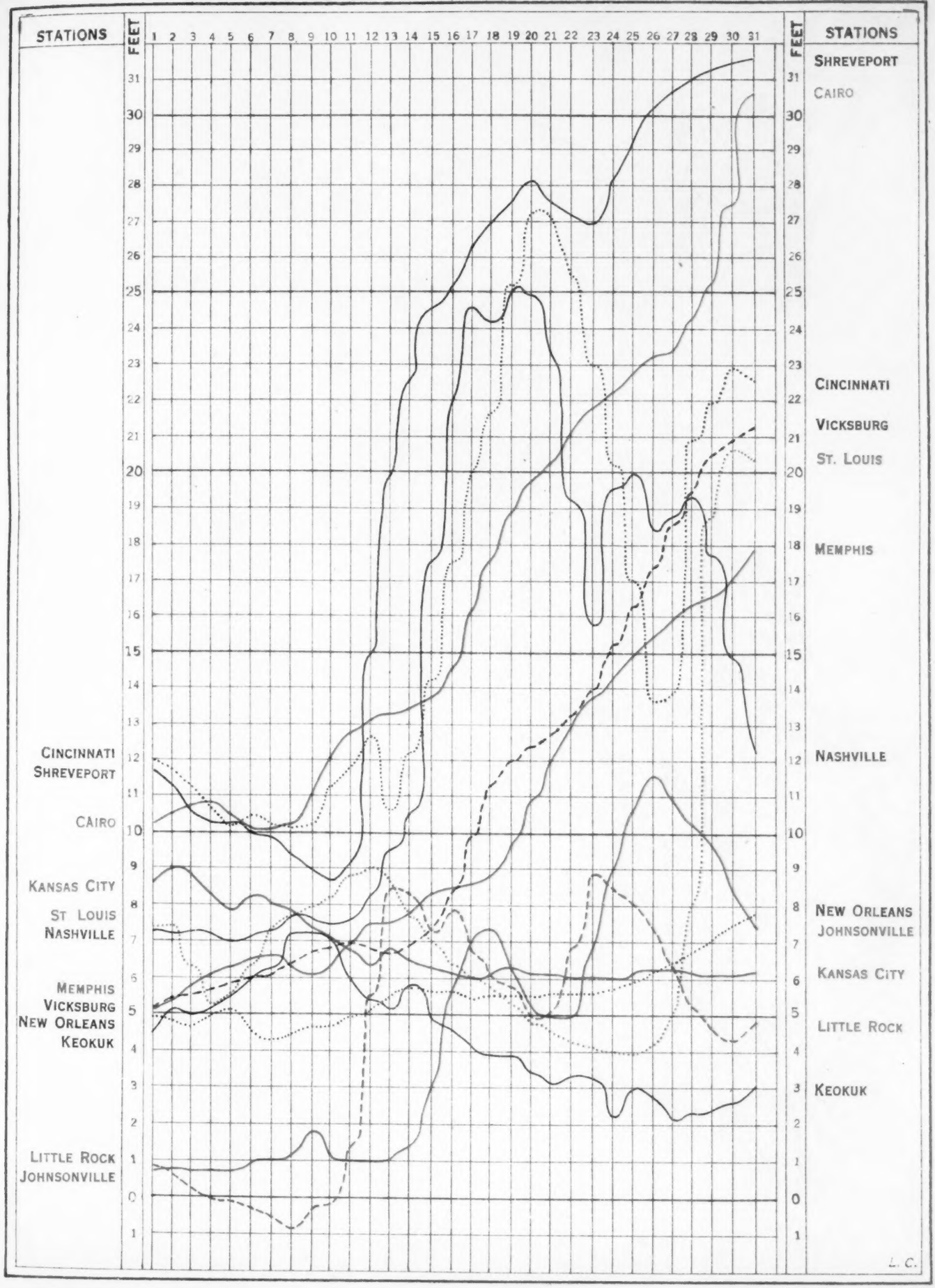
Instrument: Wiechert, vertical; Milne horizontal pendulum, North; in the meridian.

Instrumental constant $\frac{T_0}{18}$. Pillar deviation, 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1919. Oct. 1	.....	P	19 40 25	.....	.....	.....	.....	
		M	19 42 33	.....	*200	.....	.....	
		F	19 47 28	.....	.....	.....	.....	
3	.....	P	10 00 29	.....	.....	.....	.....	
		S?	10?13 51	.....	.....	.....	.....	
		L	10 18 41	.....	.....	.....	.....	
		M	10 27 32	.....	*400	.....	.....	
		F	11 11 18	.....	.....	.....	.....	
8	.....	P?	5 04 53	.....	.....	.....	.....	
		L	5 23 34	.....	.....	.....	.....	
		M	5 35 22	.....	‡800	.....	.....	
		F	7 14 43	.....	.....	.....	.....	
10	.....	P	1 08 01	.....	.....	.....	.....	
		L	1 09 00	.....	.....	.....	.....	
		M	1 09 30	.....	*1,000	.....	450	
		F	2 54 14	.....	.....	.....	.....	
12	.....	L	23?09 48	.....	.....	.....	.....	
		M	23 11 16	.....	*200	.....	.....	
12	.....	M	23 51 06	.....	*200	.....	.....	
13	.....	F	00 14 43	.....	.....	.....	.....	
14	.....	M?	12 04 32	.....	*50	.....	.....	May not be seismic.
21	.....	L?	22 09 15	.....	.....	.....	.....	
		M	22 15 09	.....	*400	.....	.....	
		F	22 32 51	.....	.....	.....	.....	
27	.....	L	4 22 17	.....	.....	.....	.....	
		L	4 23 35	.....	.....	.....	.....	
		F	4 28 17	.....	*100	.....	.....	Small but marked.

* Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, October, 1919.



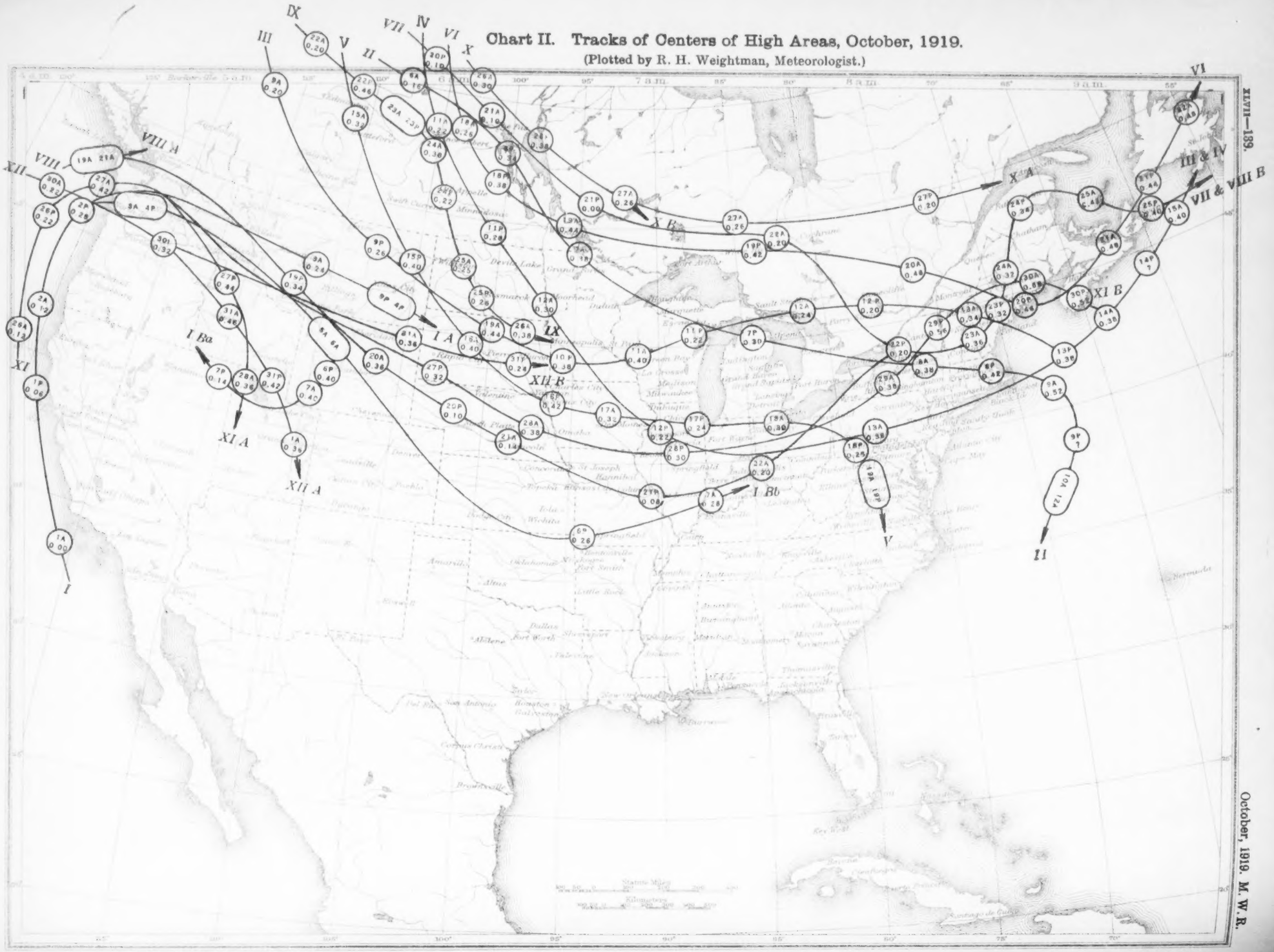


Chart II. Tracks of Centers of High Areas, October, 1919.
(Plotted by R. H. Weightman, Meteorologist.)
XLVII—189.
October, 1919. M. W. R.

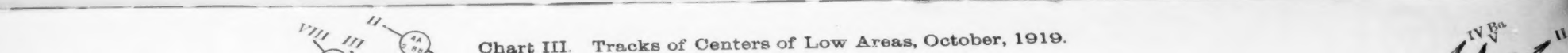


Chart III. Tracks of Centers of Low Areas, October, 1919.

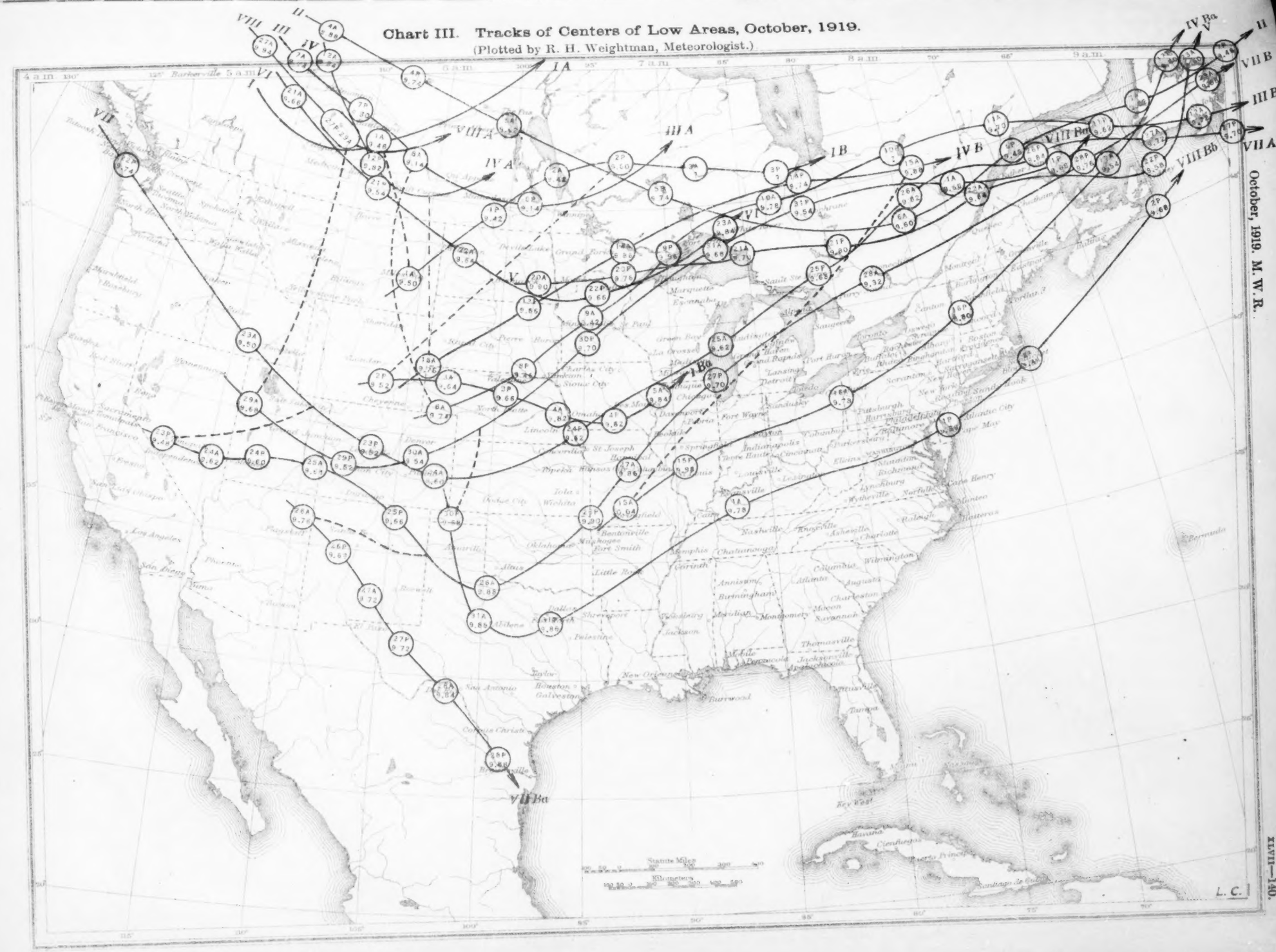


Chart III. Tracks of Centers of Low Areas, October, 1919.
(Plotted by R. H. Weightman, Meteorologist.)
October, 1919. M. W. R.
XLVII—140.
L. C.

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, October, 1919.

Chart V. Total Precipitation, Inches, October, 1919.

Chart V. Total Precipitation, Inches, October, 1919.

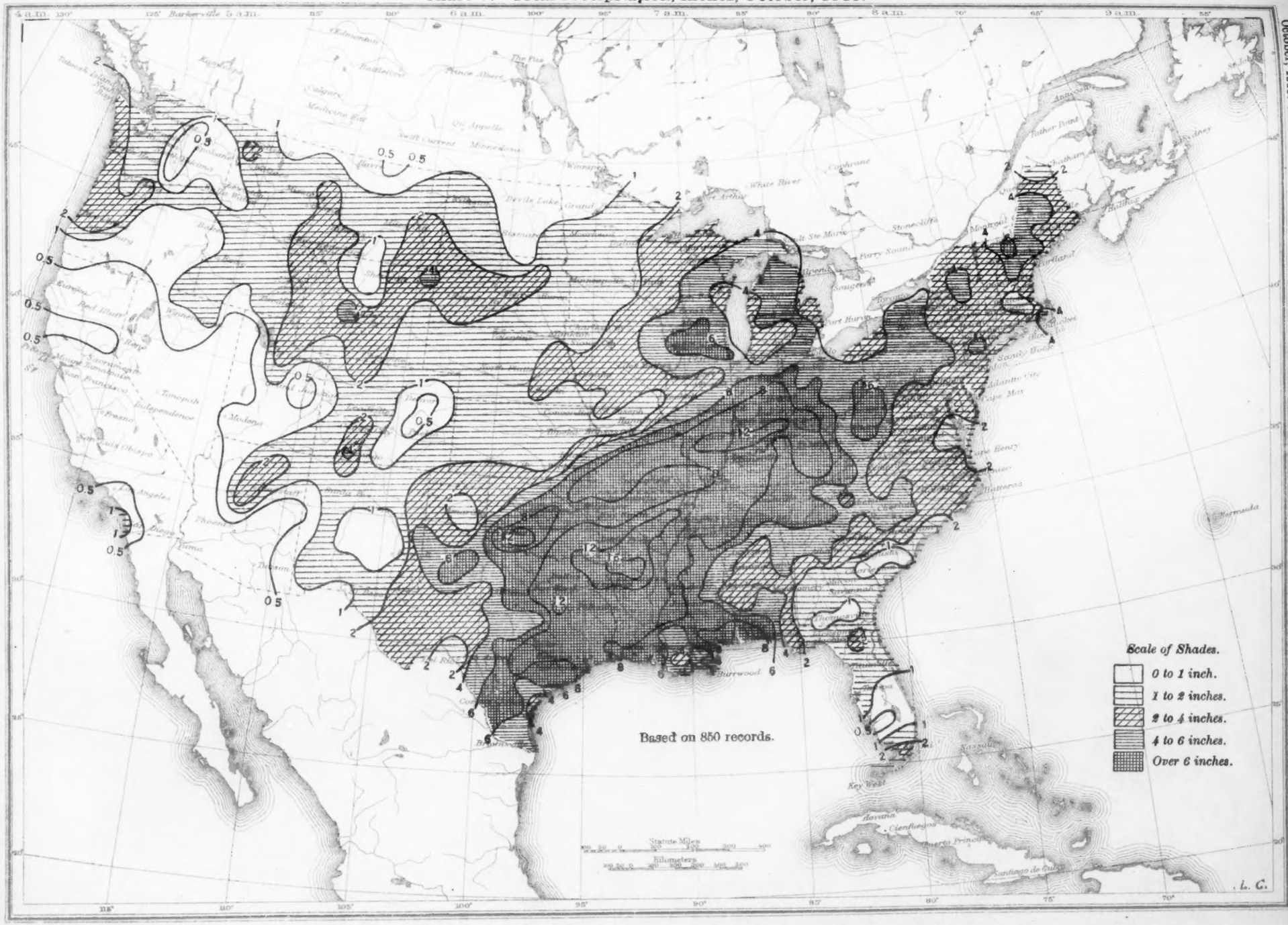


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, October, 1919.

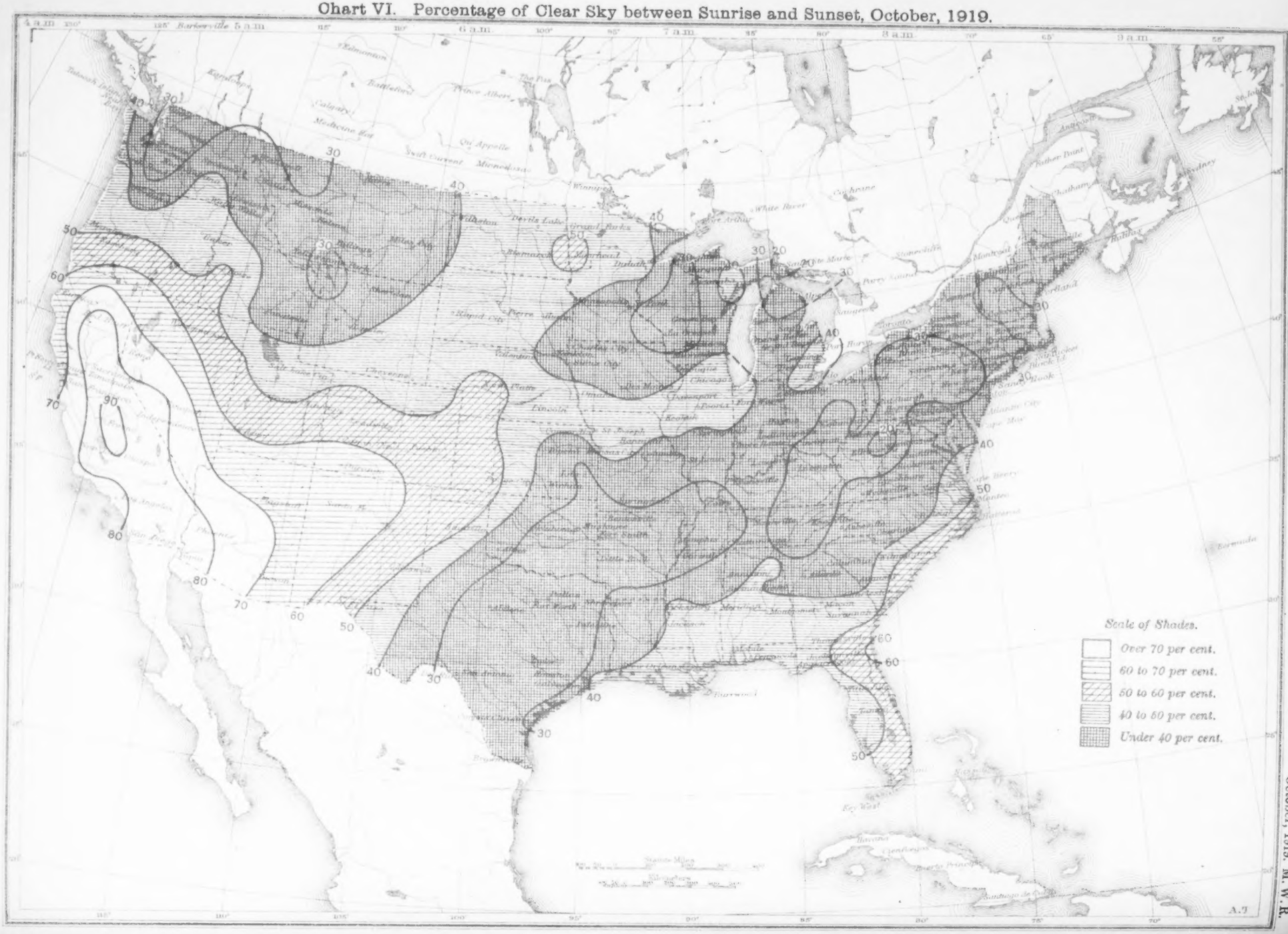


Chart VII. Isobars and Isotherms at Sealevel: Prevailing Winds, October, 1919.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, October, 1919.

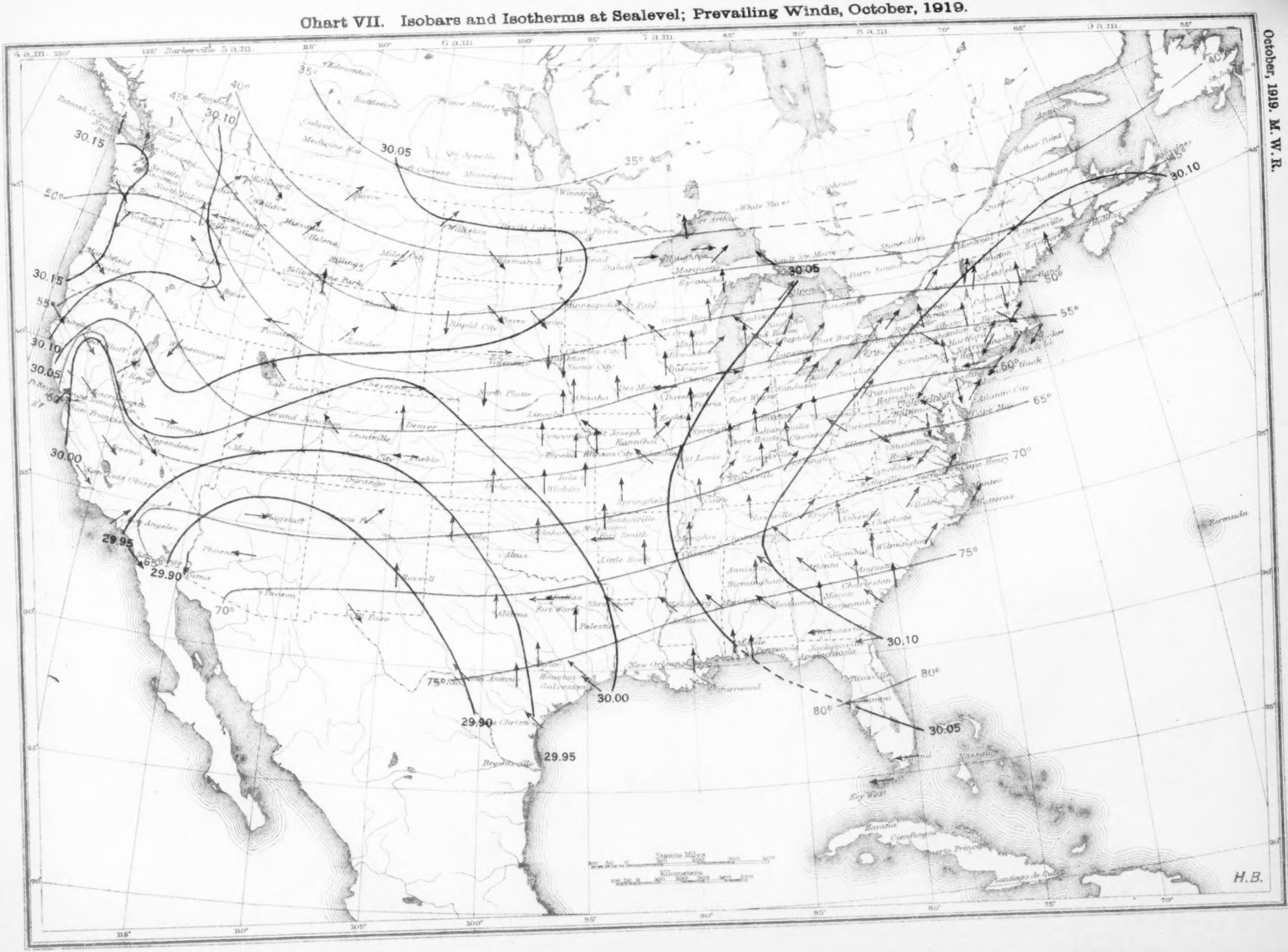


Chart IX. Weather Map of North Atlantic Ocean, October 4, 1919.
(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, October 4, 1919.

(Plotted by F. A. Young.)

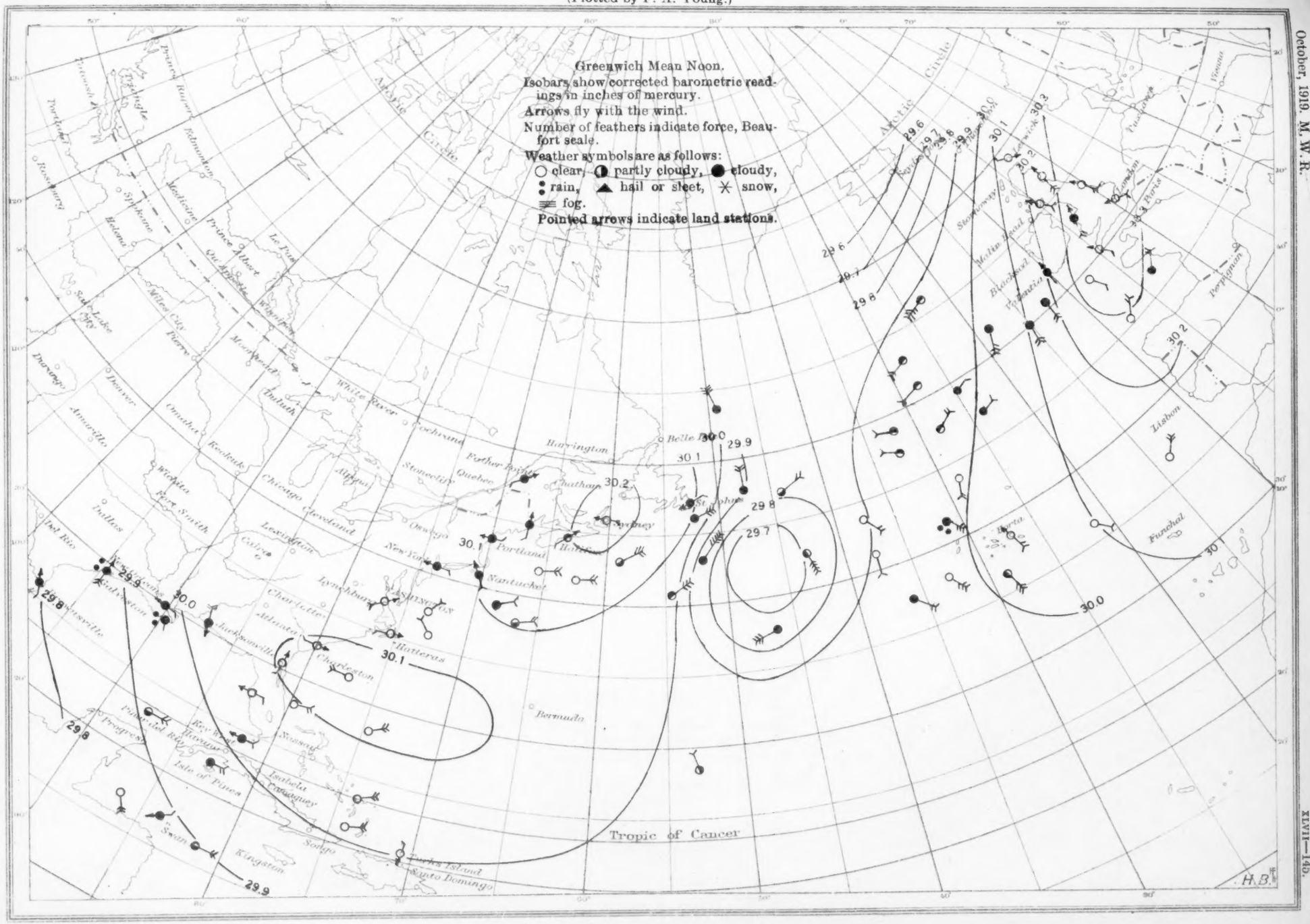


Chart X. Weather Map of North Atlantic Ocean, October 5, 1919.

(Plotted by F. A. Young.)

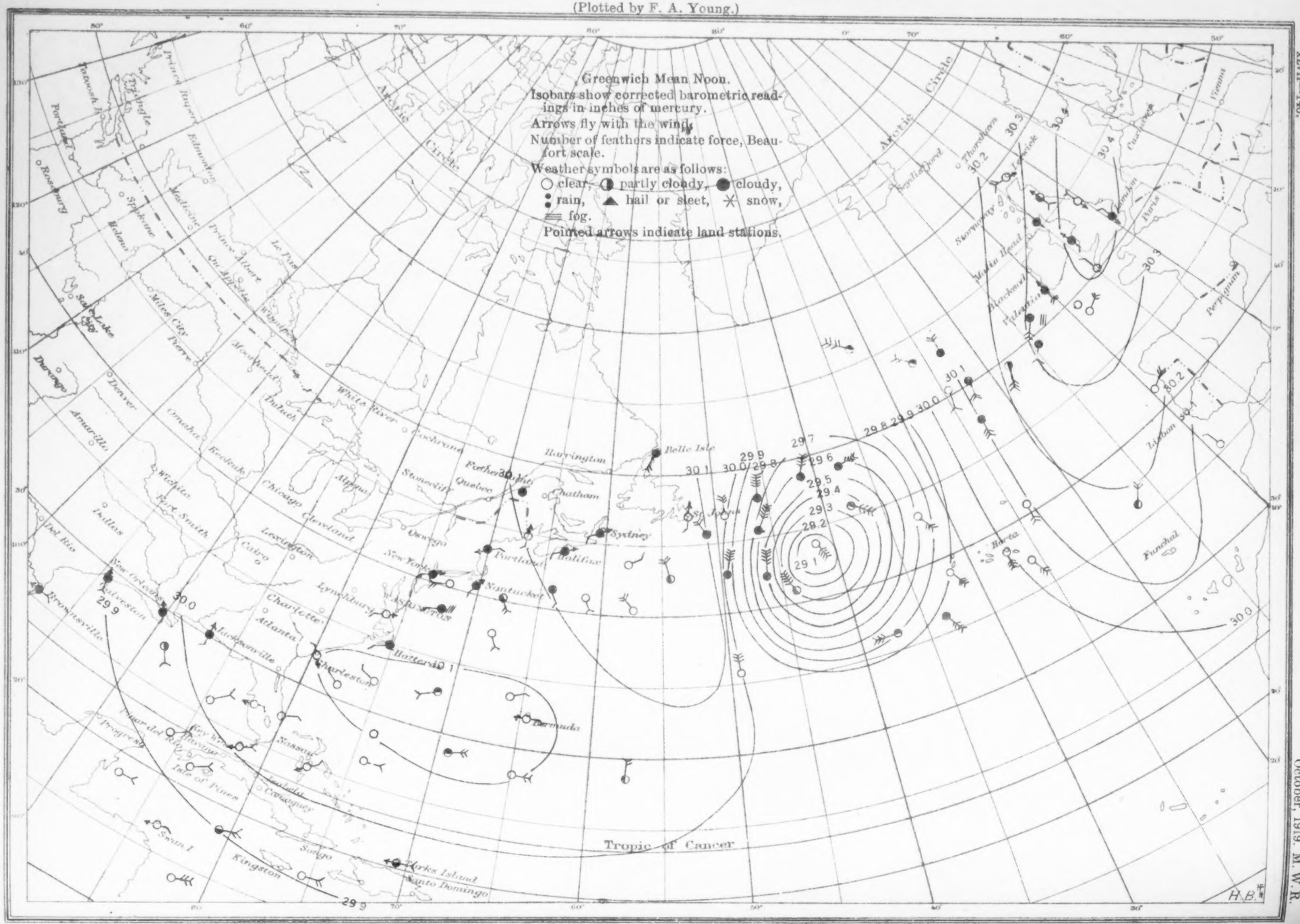


Chart XI. Weather Map of North Atlantic Ocean, October 6, 1919.

(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, October 6, 1919.

(Plotted by F. A. Young.)

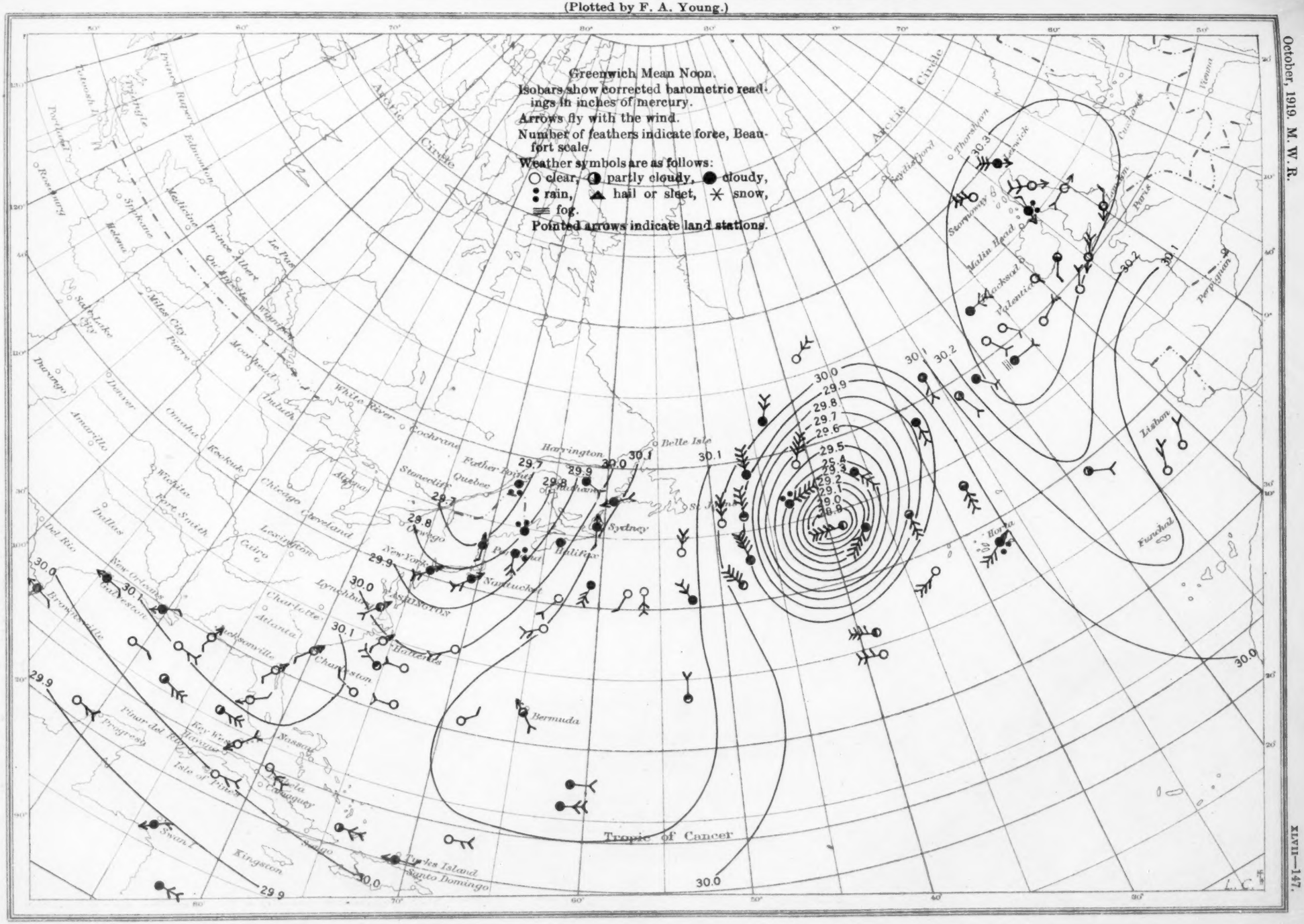


Chart XII. Weather Map of North Atlantic Ocean, October 29, 1919.

(Plotted by F. A. Young.)

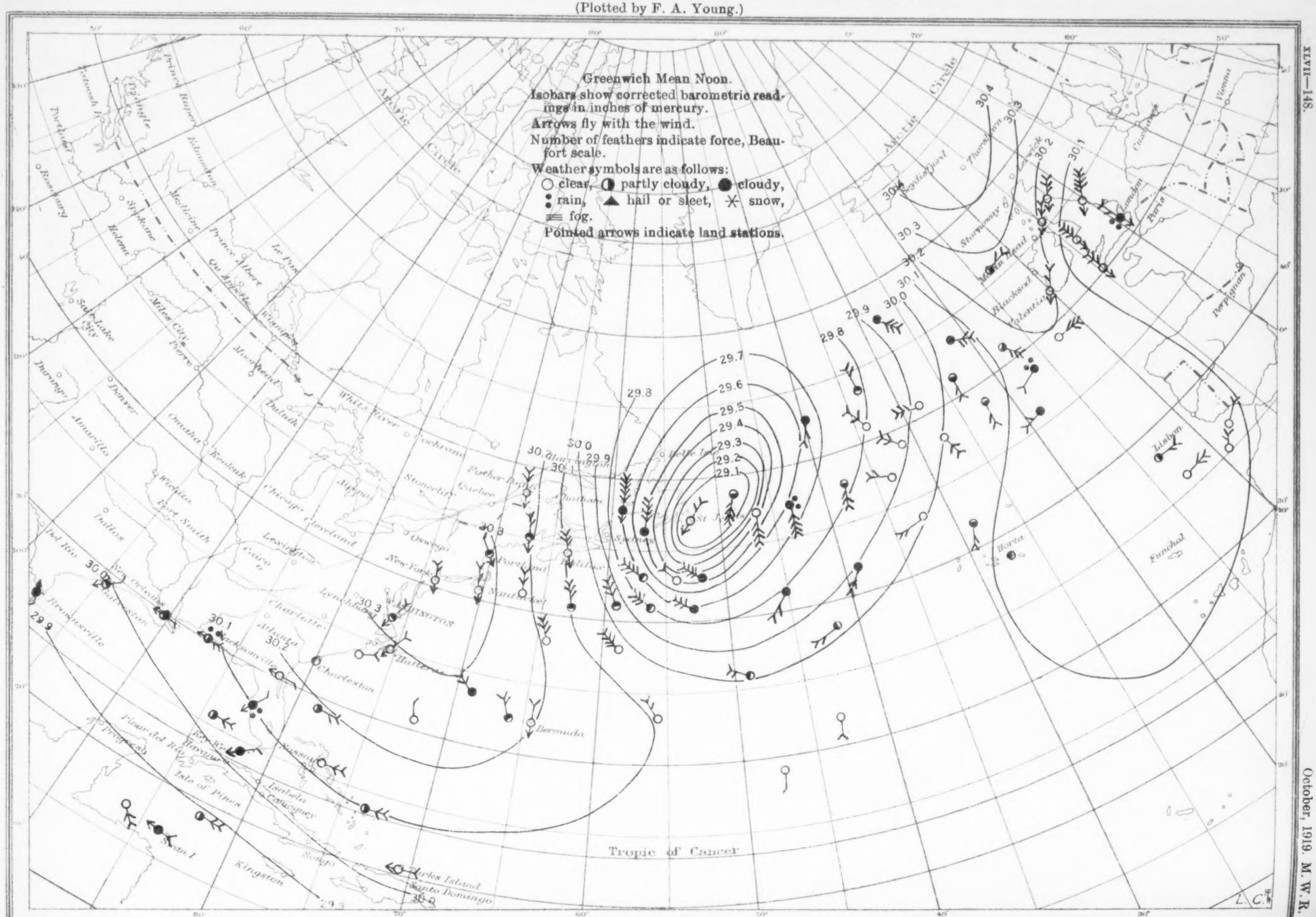

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Arctic Circle
Tropic of Cancer
Bermuda
Charleston
Kingston
Santo Domingo
Funchal
Horta
Lisbon
Paris
Valentia
Blacksod
Stornoway
Thorshavn
Reykjavik
Vienna
Copenhagen
Portsmouth
Yarmouth
Quebec
Chicago
Cleveland
Buffalo
Toronto
Winnipeg
Duluth
Omaha
Denver
Pierre
Miles City
Swift Current
White River
Modena
Kamloops
Prince Albert
Prince Rupert
Edmonton
Port Simpson
Tatoosh I.
Roseburg
Portland
Seattle
Salt Lake City
Thorington
Amarillo
Dodge City
Kansas City
Concordia
Dubuque
Rockford
Oswego
Albany
Portland
Boston
New York
Harrisburg
Cairo
Lexington
Wichita
Fort Smith
Dallas
Abilene
Del Rio
Brownsville
New Orleans
Galveston
Jacksonville
Charlotte
Atlanta
Augusta
Hatteras
Key West
Havana
Isle of Pines
Isabela
Caracas
Curaçao
Swan I.
Grand Turk
Turks Island
Port au Prince
Jamaica
Progreso
Tampico
Vera Cruz
Tuxpan
Belize
Merida
Campeche
Coatzacoalcos
Frontera
Minatitlan
Salina Cruz
Acapulco
Manzanillo
Mazatlan
Guaymas
Yuma
Tucson
Roswell
Abilene
Fort Worth
Shreveport
Memphis
Nashville
Louisville
Indianapolis
Detroit
Toledo
Buffalo
Erie
Pittsburgh
Parkersburg
Lynchburg
Norfolk
Hatteras
Cape Henry
Wilmington
Charleston
Savannah
Jacksonville
Tallahassee
Pensacola
Mobile
Vicksburg
Meridian
Montgomery
Columbus
Cincinnati
Dayton
Cleveland
Sandusky
Toledo
Grand Haven
Milwaukee
Green Bay
Marquette
Duluth
Minneapolis
St. Paul
La Crosse
Dubuque
Davenport
Peoria
Springfield
St. Louis
Cairo
Paducah
Evansville
Terre Haute
Indianapolis
Fort Wayne
Chicago
Milwaukee
Madison
La Crosse
Minneapolis
St. Paul
Duluth
Moorhead
Devils Lake
Williston
Bismarck
Dickinson
Miles City
Billings
Havre
Glasgow
Medicine Hat
Calgary
Edmonton
Prince Albert
Battleford
Qu'Appelle
Winnipeg
Swift Current
Moose Jaw
Regina
Estevan
Minnedosa
Brandon
Winnipeg
Port Arthur
Parry Sound
Toronto
Kingston
Ottawa
Montreal
Quebec
Father Point
Sydney
Halifax
St. John
Eastport
Portland
Boston
Nantucket
New Haven
Hartford
Albany
Syracuse
Rochester

Chart XIII. Weather Map of North Atlantic Ocean, October 30, 1919.

(Plotted by F. A. Young.)

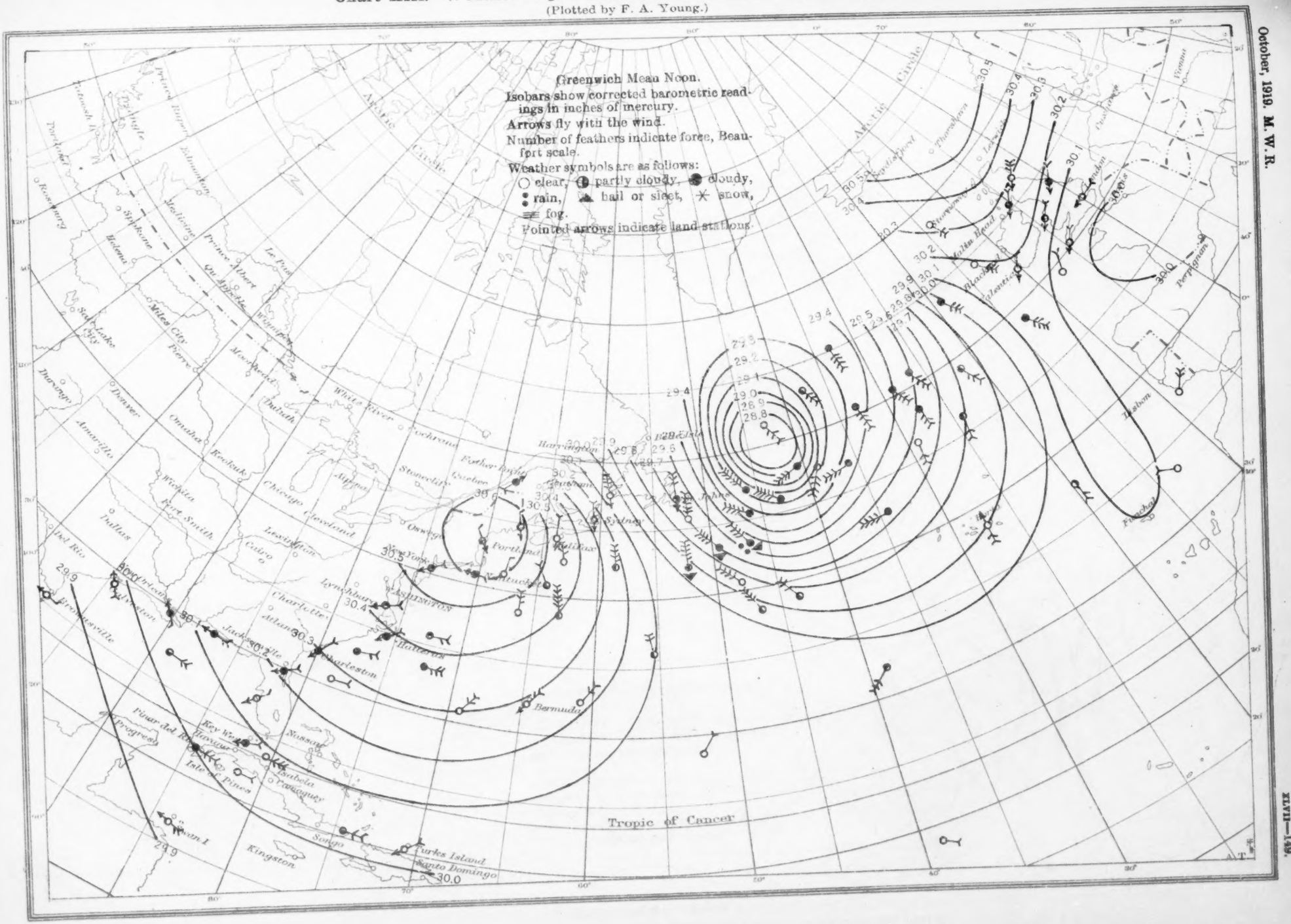
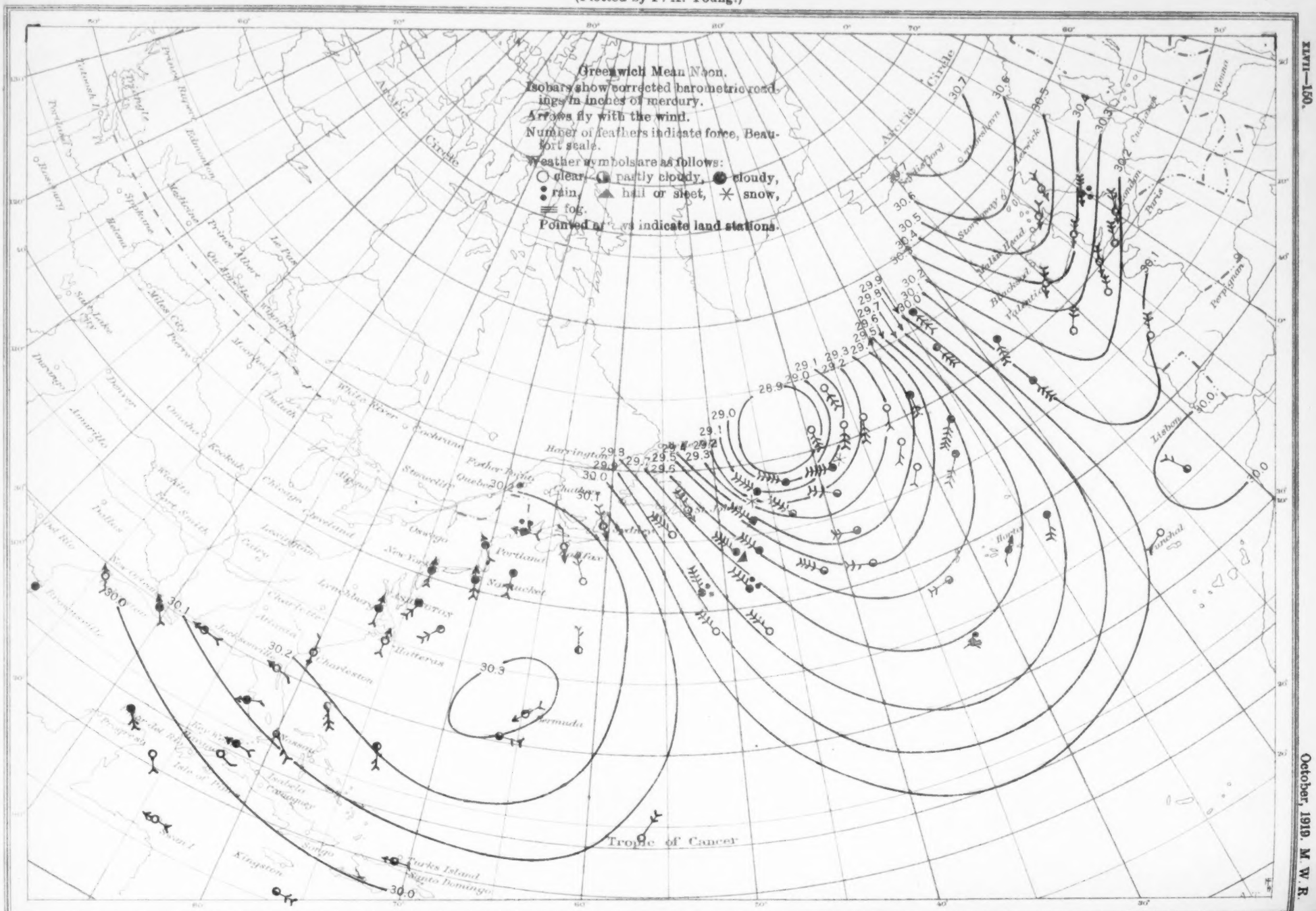
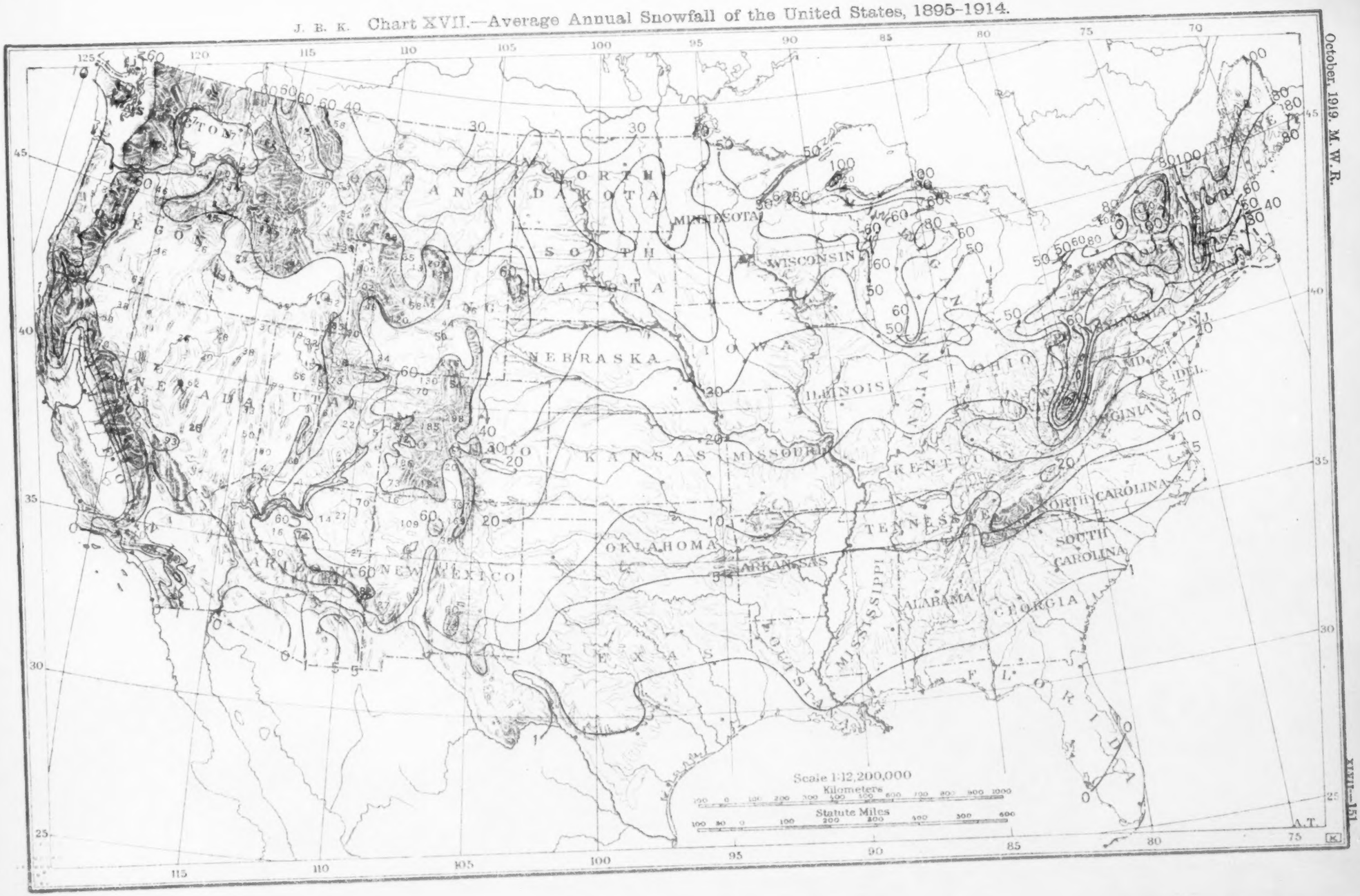

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Tropic of Cancer
Arctic Circle
Bermuda
Kingston
Turks Island
Santo Domingo
Nassau
Havana
Key West
Charleston
Jacksonville
Atlanta
Charlotte
Lynchburg
Washington
Baltimore
Atlantic City
Cape May
Harrington
Sydney
Halifax
Portland
Boston
New York
Buffalo
Toronto
Oswego
Quebec
Father Point
Stornoway
Valentia
Blacksod Bay
Valentia Head
Fastnet
Roches Point
Queenstown
Holyhead
Liverpool
Falmouth
Scilly
Portland Bill
Dungeness
Greenwich
Flushing
Ijmuiden
Helder
Borkum
Heligoland
Skagen
Thorshavn
Lerwick
Aberdeen
Kirkwall
Stornoway
Valentia

Chart XIV. Weather Map of North Atlantic Ocean, October 31, 1919.

(Plotted by F. A. Young.)


Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed ends indicate land stations.
Arctic Circle
Tropic of Cancer

J. B. K. Chart XVII.—Average Annual Snowfall of the United States, 1895-1914.



October, 1919. M. W. R.